Modern high farming

Francis Wyatt

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MODERN HIGH FARMING.

A TREATISE ON

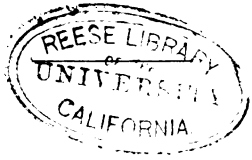
SOILS, PLANTS, AND MANURES,

BY

FRANCIS WYATT,

PROFESSOR OF AGRICULTURAL CHEMISTRY, CHEMICAL ANALYST, ETC.

AUTHOR OF "THE CHEMISTRY OF SULPHURIC ACID MANUFACTURE," "THE PHOSPHATES OF THE WORLD," ETC., ETC.



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PREFACE.

TO THE AGRICULTURIST OF AMERICA.

My Dear Sir.

The pages which I now pass into your hands are the result of much study and hard work, combined with a long special experience in matters pertaining to your vocation. They have been written solely for your information and advantage, and I trust their sincerity and utility will be found to fully justify my familiarity in thus personally addressing you.

For many years past I have had constant intercourse with men of your profession, and with the best *practical* experts in chemical manures in every part of Europe, and I judge that the time has come to impart to you not only the results of my experience with them, but also of my own personal investigations.

You will, perhaps, tell me that too much has already been written and said upon the purely chemical side of this great question; that you have bought and read books and periodicals without number, and that you are not very much further advanced to-day than you might have been had you kept your money and read no books at all.

I fancy I can hear you saying, that men of my profession have not yet found out the secret of imparting knowledge to men of yours; that where *you* have too little theory, *they* have too little practice, and that their unfortunate habit of wrapping round their teachings a dark mantle of scientific words which you do not understand, has hitherto occasioned you more confusion than benefit.

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That because of this there is a lack of good special literature, I am far from pretending; indeed, I doubt not that I could derive benefit from much of it, were I to read and digest it. But I nevertheless maintain that the books on agriculture, while not above your intellect or intelligence, are, as a rule, written in a style beyond the plane of your scientific education.

Were I to offer you the best book written in the Latin tongue, treating upon a subject familiar to you, the chances are ten to one that you would not comprehend a word, and the book would be tossed into a corner. Should one of your children — having been taught to read and translate the Latin language — stumble upon this book, and read it to you in your own mother tongue, you would be struck with wonder at the value of its truths and the simplicity of its lessons.

I fancy this is exactly the case between you and our contemporary scientists, who, persisting in addressing you in unfamiliar language, are answerable for your now putting a number of good books, that are written for you, "on the shelf."

My earnest endeavor has been to bear all these things in mind; thus, while seeking not to deviate one inch from the broad line laid down by true agricultural chemistry, I have sought to treat each subject in the plainest language possible.

If I succeed in doing no more than lay the foundation upon which you can pile up future knowledge; if I merely convince you of the necessity for thought, study and experiment, I shall consider that I have aided you in making the first great stride in the right direction, and shall find in that fact alone a sufficient reward for the service I have performed.

I am, my dear sir,

Very truly yours,

FRANCIS WYATT.

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INDEX.

CHAPTER I. PAGE

General Introductory Remarks — Influence of Climate — Origin of Scientific Agriculture — Its Progress in America 5

CHAPTER II.

Theory of Scientific Agriculture — Formation of the Globe — Its Temperature — Composition of the Earth — Its Principal Rocks — Chemistry of Vegetation — Necessity for Geological Knowledge — Remarks on Drainage and Irrigation 9

CHAPTER III.

Minerals Necessary and Injurious to Plant Life — How Plants Absorb Their Food — The Gases and Their Various Transformations — Nitrogen — Phenomenon of Nitrification in the Soil — Sources of Nitrogen — Its Manufacture — Its Fixation — Its Assimilation — The Necessity for Its Application as Manure 13

CHAPTER IV.

Phosphates — Discovery of their Active Principle — Use of Bone Manure — Discovery of Mineral Phosphates — How They Occur in Nature — Their Form in the Soil — How They are Made Soluble — How They are Assimilated by Plants — Migrations of Phosphorus — The Necessity for Artificially Introducing Phosphoric Acid as Manure 18

CHAPTER V.

Potash: Its Action on the Soil — Is it Essential to Plant Life? — Results of Direct Experiments — Its Necessity Made Clear — Sources of Its Supply — Lime — The Liming of Soils — Its Chemical Action — Its Absorbing Powers — Its Action on Sulphurous Ores — Its Action on Iron — Alumina and Phosphoric Acid in the Soil — Necessity for Its Abundant Use 23

CHAPTER VI.

How Soils Lose Their Nitrogen — Table of Proportions — Necessity of Soil Analysis — Table of Physical Elements and Chemical Constituents 28

CHAPTER VII.

Physically Perfect Soils — Strong and Light Soils — How to Amend Clayey Land — Clay Burning — Treatment of Sandy Soils — Green Crops as Manure — Remarks on Disintegration — "Fairy Rings:" Their Existence Explained — How to Keep Pace with the Times 33

CHAPTER VIII.

Progress of the Manure Trade in the United States — Low Price *versus* Real Value — How the Farmer is Swindled — Bogus Manures — Necessity for Analysis Demonstrated — How to Stamp Out the Evil — Advice to Manufacturers 38

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CHAPTER IX.

The Different Kinds of Manure — Notes on Vegetable Manures — Animal Products — Their Annual Reckless Waste — Estimate of the Loss to Agriculture — Hints on Their Preservation and Utilization — Guanos Described and Analyzed — Their Variable Quality — Fish Manures — Table of Nitrogenous Substances 44

CHAPTER X.

Farm-Yard Manures — Composition of Their Liquid and Solid Elements — Comparative Value of Absorbents, with Analyses — Composition of Various Straws — Superior Value of the Liquid Substance — How to Preserve and Utilize it — Treatment of Manure Heaps — How to Complete Their Value as Fertilizers — Their Decomposition — Formation and Description of Humus — Experiments on Freshly-Made and Fermented Manures — Results of Each Experiment — General Remarks 50

CHAPTER XI.

Mineral Manures — Bones, and What They Taught Us — Sulphuric Acid and Nitrate of Soda — Bone Ash — Animal Charcoal, or Bone Black — Bone Meal — Sulphate of Ammonia: Its Great Power of Decomposing Other Manures — How to Detect Impure Nitrate of Soda — Nitrate of Potash, or Saltpetre — Phosphate of Lime — River Phosphates — Canadian Phosphate — A Ridiculous Extortion 57

CHAPTER XII.

Sulphur — Its Occurrence in Nature — The Mines of Sicily — The Refining Process — Iceland Soufrières and Solfataras — Use of Sulphur in Manufacture — Pyrites and How They Occur — Analytical Tables — General Annual Consumption — The Mines of Spain Described 69

CHAPTER XIII.

Sulphuric Acid Manufacture — Sketch of Its Past History — Pyrites Burning — Glover's Towers — Hints on the Construction of Leaden Chambers — Chemistry of the Process — Denitration — Gay-Lussac Towers — General Remarks 75

CHAPTER XIV.

Superphosphates — Uncertainty of Their Composition — Their Manufacture Described — How to Manipulate When Made — Nature of the Decomposition Process — Explanation of the Loss in Weight — What is Soluble Phosphate? — Discussion of Its Merits in the Field — Its Action in the Soil — Necessity for Careful Analysis Made Further Manifest — Precipitated Phosphates: Their Manufacture, Their Virtues and Superiority — Use of Complete Manures, with Examples and Statistics — Remarks on Home-made Chemical Manures 80

CHAPTER XV.

Chemical Analysis — How to Read and Understand Chemists' Certificates — Use of "Complete" and "Simple" Manures — Conclusion 89

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MODERN HIGH FARMING.

CHAPTER I.

GENERAL INTRODUCTORY REMARKS —— INFLUENCE OF CLIMATE —— ORIGIN OF SCIENTIFIC AGRICULTURE —— ITS PROGRESS IN AMERICA.

AGRICULTURE may be truly said to be the foundation stone or rock upon which is built every nation's riches, since the productions of nature are the materials of art; and it is undeniable that the prosperity of the whole human race has always been dependent upon three powerful physical agents — Climate, Soil, and Food.

The first thing necessary to the cultivation of a community is wealth, as without it there can be no leisure, and without leisure no opportunity for the development of the intellectual faculties and the acquisition of that knowledge upon which the progress of all civilization depends.

As will be shown by a very brief retrospective examination, the rapidity with which capital is accumulated in a new country must vary in accordance with the nature of its climate and the fertility of its soil — the latter regulating the returns made to any given amount of labor and care, the former regulating the energy and the continuity of that labor.

The only portions of the American Continent which could lay any claim to civilization before the appearance of Europeans, were

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those comprised in its very hottest parts — the tract which stretches from the Isthmus of Panama to Mexico in the northern, and to Peru in the southern tropic.

If we momentarily set aside — to be dealt with later on — the questions of geological and chemical varieties of soil, we may at once assume that the two regulating causes of fertility are combined heat and moisture — the fruitfulness or sterility of the land being dependent upon their abundance or deficiency. Now as regards moisture, neither in North nor in South America does one great river empty itself into the Pacific — the whole of them being upon the eastern coast; and as regards heat, nature has been equally partial in its endowment of the west. Whether the natural difference of temperature resulting from this curious phenomenon forms part of some universal scheme, or whether we are dealing with a peculiar instance, we will not stay to discuss; the fact and its influence upon the early history of this country are indisputable — the two great conditions of fertility not having been naturally united in any part of the entire continent north of Mexico. The primitive inhabitants were, therefore, in this difficulty: on one side they wanted heat, while on the other they had no irrigation; and the result was that until the sixteenth century, when the acquired knowledge of Europeans was brought to bear upon the difficulty, there existed no agriculture, no accumulation of wealth, and no progress north of the twentieth parallel, even toward that rough civilization so easily attained by the nations of India and Egypt. For a direct contrast to what went on in the north, we have now only to turn to the narrow tract of land lying south of the twentieth parallel, of which the peculiar configuration caused by the contraction of the continent until it reaches the Isthmus of Panama — secures to it a large extent of coast.

This southern part of North America thus assumes the character of an island — with that feature of an insular climate, the increase of moisture consequent upon the watery vapor arising from the sea, and the augmentation of rainfall natural to its vicinity. It was therefore the only portion possessing a natural combination of the

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two essential elements — its equatorial situation giving it heat, and the shape of its land humidity; and it was also the only portion which arose out of barbarism.

Without going so far back into the history of this country for examples in favor of our argument, we need only have turned to the sandy plains of California, where, until they were quite recently subjected to irrigation by the ingenuity, enterprise and enormous capital of a civilized community, nothing met the traveler's mournful gaze but the contemplation of a sterile desert; but where are now displayed all that marvelous exuberance of soil that has never failed to characterize a virgin country when the natural physical elements have not been wanting.

It would be useless in such a work as this to attempt to trace the progress of agriculture back to the wandering husbandmen who roamed from place to place with their immense flocks until, by the eventual adoption of a fixed abode and the expenditure of time and labor, a certain price or value was accorded to their land; and we must therefore content ourselves with the broad statement that until long after the commencement of the present century the agricultural arts, as practiced by the most advanced of the European communities, differed but in trifling details from those exercised by the ancient Romans and described in Columella's great work "*De Re Rustica.*"

Alarmed by the falling off of crops and general signs of the exhaustion of their soils, the European scientists have been moved to bring to bear upon the question the acquired knowledge of the geologist, botanist and chemist, and to such men as Liebig, Lawes, Gilbert, Dumas, Boussingault, Barral, Malagati, Payen and George Ville we are now indebted for a progress which has enabled us to become almost *independent of natural causes*, and for a literature of applied and applicable truths second to none in value and importance throughout the whole range of scientific investigation.

That a goodly number of intelligent American agriculturists have awakened to all this, and have long been following in the footsteps of their European brethren, is proved by the extension of

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sulphuric acid and fertilizer manufacture in this country ; but there still remains an immense majority of farmers great and small, high and low, in north, south, east and west, who have made no study of scientific agriculture ; who have not kept pace with the times ; who even look with suspicion and distrust upon those who would enlighten them ; and who are to-day unable to understand why their annual crops, though perhaps rotatory, are no longer so abundant, nor of so good a quality as they were wont to be thirty or forty years ago. Ours being essentially an age of thought and progress, the time has come when every man must realize that agriculture can only remain a profitable pursuit, on the condition of yearly obtaining from every acre a maximum and cheap return, and that in order to succeed in this he must restore to the soil those elements which it once contained, but which in the process of nourishing the plants, have been absorbed and taken away.

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CHAPTER II.

THEORY OF SCIENTIFIC AGRICULTURE —— FORMATION OF THE GLOBE —— ITS TEMPERATURE —— COMPOSITION OF THE EARTH —— ITS PRINCIPAL ROCKS —— CHEMISTRY OF VEGETATION —— NECESSITY FOR GEOLOGICAL KNOWLEDGE —— REMARKS ON DRAINAGE AND IRRIGATION.

The theory of scientific agriculture is based upon a complete knowledge of the nature of soils, plants, animals and manures, and it is evident that until these elements are thoroughly understood, no attempts at improvement or plans for increased production can possibly be successful. It is curiously illustrative of the general ignorance that very few people know anything of the earth they tread or the soil they cultivate, in what way it was formed, or what is its composition. How, then, can they imagine the mighty inundations and the terrible upheavals? How conceive anything of that gigantic disemboweling of the earth-monster, and of the awful torrents of burning lavas which it has vomited forth? Can they realize that our tallest mountains, even those which from their height are covered with perpetual snow, were once submerged in rolling seas? or that the rocks and cliffs we meet with in our plains are nothing more than agglommerated masses of organisms that swarmed the waters?

We might very easily allow ourselves to be carried far away by this seductive topic, but must needs confine our pen for present purposes to a brief synopsis of elementary facts which, if they serve no other purpose, may induce some of our readers to "seek for more."

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Geologists agree in supposing that our globe was once a glowing mass of fire, that the formation of the earth's crust is due to the gradual process of cooling. They point to its figure and compare it to that of a liquid rotatory body acted upon by gravity, and from this deduce evidence of its original fluid state. The volcanoes actually in a state of eruption prove the earth to have an internal temperature independent of the heat of the sun; and from observations made in the deepest mines all over the world, it would appear that this temperature, below a depth of one hundred feet, increases 1° Fahrenheit in every twenty yards; so that, presuming the rate of increase to be constant, at twenty thousand yards we should arrive at a low red heat, and by descending still lower, this would be sufficiently increased to maintain all kinds of minerals in a state of fusion.

The different species of rocks of which the earth is composed, may be divided into three groups.

FIRST—SANDSTONES.—These belong to every geological period, are sedimentary and of infinite variety, though differing only in the size of the grains of which they are composed and in their degree of texture and compactness. When occurring in connection with clays, marls, chalks, iron-ores, glauconite, or felspar, in varying proportions, they undergo transformations which convert them into vegetable soils.

SECOND—LIMESTONES.—These are organically formed rocks, made up of the remains of animal life, corals, shells and bones, cemented and so intimately bound together as to necessitate the minutest investigation for their recognition.

THIRD—GRANITE.—These are igneous rocks, of volcanic origin, and owe their formation to the cause of interior heat. They are composed of numerous distinct orders of crystals such as felspar, mica, gneiss, quartz and hornblende, mixed up and not in regular beds.

The history of these three great groups of rocks may therefore be aptly termed the history of the earth, since their decomposition under the combined influence of the atmosphere and water, during a

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long period, ultimately produces highly fertile soils containing silicates of aluminum, potassium, sodium, magnesium, iron, phosphates, sulphates, and chlorides.

The soil at first resulting from this gradual decomposition forms very thin layers, in which only the lower orders of plants find sufficient food to fructify — deriving from the air and the rain their carbon, hydrogen, oxygen and nitrogen. In the natural process of death and decay, these fresh elements of fertility — in various states of combination — are transferred by the plants to the soil, which is thus enabled to afford nourishment to a higher vegetation, and, by attracting to it the animals in search of vegetable food, receive from them other elements conducive to the highest fertility.

The study of Geology — even if only elementary — will therefore enable the agriculturist to accurately guage the natural resources of his country, and will teach him how to adapt his ideas upon drainage, irrigation, plowing and sowing to the surrounding circumstances of soil and climate. He will learn to mix and combine different soils, and understand that certain overlying beds on his lands may not at all resemble in composition or be derived from the underlying rocks, but may have been carried from immense distances and deposited by water. Then it may frequently happen that in some fields he may have a very stiff and unworkable clay — which his geological map would show to reposé upon a deposit of sand or of limestone, and in such a case he could at once (after previously verifying the fact by some preliminary boring or deeper ploughing) open up a quarry and supply his clays with the necessary elements for their conversion into loam.

The acquirement of knowledge will naturally induce us to seek by art to assist or even to improve upon nature, and well-considered preferences will be accorded to certain cultures and breeds of cattle, while into the soil will be introduced those elements of fertility in which it has been proved to be deficient.

Sufficient attention will be paid to drainage, the necessity of freeing the land from an excess of water being even greater than the introduction of fertilizing elements ; for, although under proper con-

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ditions the latter will undoubtedly increase the quantity and value of the crops, too much water will effectually prevent us from drawing any crops at all. Nothing, therefore, can ever be done with land anywhere, if it be not properly drained where there is too much moisture, or properly irrigated where the necessary natural water supply is not forthcoming. It is because of the vital importance of this question that we are thus emphatic at this early stage. To ascertain whence such an excess of water proceeds is not by any means a matter of difficulty; a very damp climate, a spongy and retentive soil, the existence of underground springs—all these or any of them may be the causes of disastrous effects, which can be easily remedied by those possessed of such knowledge as we have endeavored to describe. In the first of the cases named, the evil may be overcome by ordinary surface drainage, but in the second, it is only after ascertaining the true composition of the soil, that we can effect such mixtures with other soil, or combinations with lime or sand, as may suggest themselves as necessary, while in the third case, the construction of deep underdrains alone will carry off the water from the sub-strata without allowing it to reach the surface.

Wherever there exists a faulty or careless system of drainage, no correct estimate of the agricultural value of a property can possibly be formed, for although from its excessive dampness a soil may remain unproductive, it may, nevertheless, contain all the necessary elements of fertility.

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CHAPTER III.

MINERALS NECESSARY AND INJURIOUS TO PLANT LIFE —— HOW PLANTS ABSORB THEIR FOOD —— THE GASES AND THEIR VARIOUS TRANSFORMATIONS —— NITROGEN —— PHENOMENON OF NITRIFICATION IN THE SOIL —— SOURCES OF NITROGEN —— ITS MANUFACTURE —— ITS FIXATION —— ITS ASSIMILATION —— THE NECESSITY FOR ITS ARTIFICIAL APPLICATION AS MANURE.

The presence of a considerable number of mineral substances in the soil is essential to the healthy growth of plants. But, while some of these minerals, such as magnesium, manganese and fluor, take no part in furthering, others are positively fatal to their development. Thus one per cent. of sulphate of iron will render a soil unproductive, and instances are not wanting where one per cent. of chloride of sodium (common salt), in very dry regions, has killed all vegetation and produced sterility.

We may therefore consider that the principal essential substances demanded by a healthy and robust plant life, are the following :

FIRST.—Oxygen, hydrogen, carbon and nitrogen, which vegetables take in and assimilate from the air, through their leaves or respiratory organs.

SECOND.—Phosphorus, potassium and lime, contained in the soil and absorbed by their roots.

Commencing with the three gases — oxygen, hydrogen and carbonic acid, we find that they exist in abundance, both in the air and in the soil. A combination of the two first in the form of rain, dew, springs or irrigation, furnish, with the carbonic acid, the necessary

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elements to form the carbon-hydrates — *glucose*, *cellulose*, *dextrine* and *starch*, or the hydro-carbons — *oils*, *fats*, *essences* and *resins*.

Carbonic acid gas exists in the atmosphere in the proportion of four 10,000ths, and is an union of carbon and oxygen formed by combustion, respiration, or fermentation. All kinds of fuel contain large proportions of carbon, which, combining with the oxygen of the air in the burning process, makes its escape in the form of carbonic acid gas.

In the course of his experiments Boussingault discovered that while under the influence of light, the leaves of plants absorb and decompose this gas, and that in the dark they evolve or give back a certain portion of it.

Nitrogen is very generally supposed to be assimilated either as nitric acid — a combination of nitrogen, hydrogen and oxygen, or as ammonia — a combination of nitrogen and hydrogen only. But the question is a most difficult and vexed one, which has created a vast amount of speculation and upon which very few of our best authorities have yet been able to agree.

A great many of our readers will have doubtless seen performed in their school-days, that interesting experiment first shown by Cavendish in 1786, demonstrating the formation of nitric acid from the combination of the oxygen and nitrogen of the atmosphere, under the influence of the electric spark. The presence of minute portions of nitric acid and of nitrates in the rain water, snow, and hail, is easily explained on the theory of this important discovery, and any doubts which may have existed in some minds as to the reality of the combination, were effectually and finally dissipated when M. Cloëz publicly performed the following experiment in the course of a lecture delivered to the Chemical Society of Paris, in 1861. A mixture of hydrogen and oxygen gases was burnt in the presence of nitrogen, and about 210 grammes of water resulted from the explosion, which, upon evaporation, was found to contain 3 grammes of saltpetre.

Numberless chemists have since that time devoted their attention to the problem of fixing the nitrogen of the air in some utiliza-

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ble and assimilable form, and many of them lay claim to successes which, although theoretically correct and practically realizable in the laboratory, have never yet been able to stand the test of economical industrial application.

This great question will eventually be satisfactorily solved, for we have already witnessed the remarkable phenomena of the formation of nitrates by the mere passage of atmospheric air through such porous bodies as pumice stone and chalk, previously impregnated with an alkaline solution. It is therefore highly probable that the new compound of nitrogen will be ammoniacal, commercially presented in the form of sulphate, and that the costly product now used and manufactured from the refuse liquors of gas works, will give place to an article of which the price will be comparatively nominal and the supply inexhaustible.

Until the efforts now being made, however, in all countries, are crowned with success, it behoves us to carefully turn to account all those sources of nitrogen actually at our disposal. That the combination of nitrogen and oxygen to form nitric acid actually goes on in the air, we have said enough to prove, and that a similar operation is possible in the soil we can just as easily show.

In this case the chemical action ensues under the influence of the slow combustion of the carbonized or decaying matters, left behind them by the crops, or by the leaves which have fallen from the trees and been worked into the ground.

Now, were it possible for us to allow an exhausted field to remain uncultivated for a given number of years, abandoning it to that wild and spontaneous vegetation and subsequent death and decay, which would naturally take place; we should discover that the soil had absorbed such a quantity of nitrogen, as to permit of our reaping large and repeated crops of cereals without any artificial introduction of this essential element.

But, as this course is diametrically opposed to all the rules of rational culture, and would in the majority of cases be impracticable, we cannot for a moment entertain it as a serious remedy, and must seek in other directions that which instead of necessitating the

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stoppage of any portion of our culture, will enable us to vastly increase, if not more than double our yearly production.

Having shown that nitrogen can only enter into combination and be fixed in the presence of combustion, no better agent for helping this process can well be imagined than farm-yard manure, of which in a subsequent chapter we shall have a great deal to say.

Ploughed into the field, this decomposed, rotting, or carbonized mass attracts the nitrogen during the whole course of its carbonization, and having fixed it, enables it subsequently to undergo the various transformations which render it assimilable, and allow of its passing from the soil into the plant.

In what form vegetables assimilate the nitrogen thus fixed, it is very difficult to determine; nor do any of our best authorities seem to agree upon the issue. Our own opinion, based upon the phenomenon of nitrification and the constant formation of nitrates in the soil, is that the nitrogen absorbed into the sap is brought into contact with the oxygen set free by the decomposition of carbonic acid, and thus forms nitric acid, which penetrates into all the tissues.

It may be urged against us that plants are organs rather of reduction than of oxidation, and that the nitric acid itself would — undergoing a decomposition similar to that of carbonic acid and water — be transformed into ammonia by the hydrogen then being produced; but our own researches have been sufficiently elaborate to justify us in the meantime in maintaining our ground.

That nitrogen is assimilable in its free and natural state, we positively refuse to admit, and, although it forms four-fifths of the volume of atmospheric air, and exists in appreciable quantities in the soil, only an insignificant portion would, in the absence of all combustion, be available for the nourishment of the plants.

Presuming, therefore, that carbonized materials of any kind are not sufficiently abundant to well cover the ground after each crop — and this is generally the case — we have to bear in mind that we continually take away large quantities of nitrogen, which

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unaided nature does not with sufficient rapidity replace. It is consequently necessary to artificially introduce it into the soil in some cheap, efficacious and soluble form, if we desire the equilibrium to be undisturbed, since its presence determines the dearth or abundance in the plants of nitrogenous carbon-hydrates or proteids, such as *legumine* or vegetable caseine in the leguminous species, *gluten* in the cereals, and *nicotine* in tobacco.

As at a later stage of this work we shall come back to this question under the heading of Manures, we may for the present leave the gaseous elements and pass on to those of a mineral nature, which play a no less important part in the vegetable economy.

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CHAPTER IV.

PHOSPHATES —— DISCOVERY OF THEIR ACTIVE PRINCIPLE —— USE OF BONE MANURE —— DISCOVERY OF MINERAL PHOSPHATES —— HOW THEY OCCUR IN NATURE —— THEIR FORM IN THE SOIL —— HOW THEY ARE MADE SOLUBLE —— HOW THEY ARE ASSIMILATED BY PLANTS —— MIGRATIONS OF PHOSPHORUS —— THE NECESSITY FOR ARTIFICIALLY INTRODUCING PHOSPHORIC ACID AS MANURE.

Of the absolute necessity for the presence in the soil of such minerals as phosphorus, potassium and lime, we have the most undeniable proofs; for it has been clearly shown that vegetables, though abundantly supplied with oxygen, hydrogen, carbon, and nitrogen, remained puny and devoid of vigor if deprived of mineral salts.

The form in which phosphorus is assimilated is that of phosphate —produced, first by the action of oxygen as phosphoric acid, and then by the combination of this acid with various bases, the principal of which is lime. Enormous deposits of phosphate of lime have been and doubtless will continue to be discovered in every quarter of the globe; and as, besides being an essential to plant life, it is the principal constituent of bones, we may assume that, if by some extraordinary phenomenon its source were suddenly cut off or exhausted, all vegetable and animal life would come to an end.

So far back as the year 1698 a celebrated French engineer—Vauban—writing in the *Dime Royal*, says:

"We have for a long time past been universally complaining of the falling off in the quantity and quality of our crops; our farms are no longer giving us the returns we were accustomed to;

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yet few persons are taking the pains to examine into the causes of this diminution, which will become more and more formidable unless proper remedies are discovered and applied."

Despite this warning note, it was not until after the commence ment of the present century that the English farmers began to use crushed bones as a manure, and even then they did so in blind ignorance of the principles to which they owed their virtues, as is clearly shown by an article published by one of the scientific papers of that day — 1830 — in which the writer says :

"We need take into no account the earthy matters or phosphate of lime contained in the bones, because, as it is indestructible and insoluble it cannot serve as a manure, even though it is placed in a damp soil with a combination of circumstances analytically stronger than any of the processes known to organic chemistry."

A subsequent writer upon the same subject declares that "bones, after having undergone a certain process of natural fermentation, contain no more than *two per cent. of gelatine*, and as they derive their fertilizing power from this substance only, they may be considered as having no value as manure."

That such opinions as these should have prevailed only fifty years ago seems to us all the more preposterous, because of the gigantic strides which we have made since then, and because of the singular fact, that even the Chinese were better informed than our grandfathers, inasmuch as they knew that the fertilizer was a mineral principle, and for many centuries have used burnt bones as manures.

Despite the unflagging researches of the best men of the time, it was not until the year 1843, that the Duke of Richmond, after an exhaustive series of experiments upon the soil, with both fresh and degelatinized bones, came to the conclusion that they owed their value, not to gelatine or fatty matters, *but to their large percentage of phosphoric acid!* The spark thus emitted soon spread into a flame, and a conclusive experiment shortly after published by the illustrious Boussingault, set all uncertainty at rest forever.

Numerous species of vegetables were planted in a soil rich in assimilable nitrogen, and absolutely devoid of any trace of phosphoric

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acid. *No development of these plants took place, until he had made the addition of phosphate of lime, when their growth became flourishing!!!*

Meanwhile large workable deposits of mineral phosphates were already known to exist, they having been simultaneously discovered in their respective countries, by Buckland in England, and Berthier in France; and in the course of a lecture delivered to the British Association in 1845, Professor Henslow, describing the Suffolk coprolites, suggested the immense value of their application to agriculture.

From this time may be dated the commencement of phosphate mining, and it is certainly marvelous to contemplate, not only the rapidity with which fresh deposits have been everywhere discovered and opened up; not only the millions of tons yearly raised to supply a never-failing demand, but also the fabulous amount of capital and gigantic numbers of workmen constantly and remuneratively employed in the production.

Phosphates of lime have been found in rocks of all ages, and of nearly every texture; sometimes pure; sometimes in different forms of chemical combination; in mineral fissure veins; in pockets, or filled-up cavities; in stratified beds or layers, and in intimate connection with the fossil remains and other phosphatic matter, deposited by the ancient seas. They are, however, chiefly found as:

APATITES, or Crystalline Phosphates, occurring in the gneissic rocks of the Laurentian age in North America and Norway, and in the Silurian rocks of Spain and Portugal.

COPROLITES, or Fossilized Nodules, occurring in the green sandstone, or cretaceous rocks of England, France, Belgium and Russia.

PHOSPHORITES or Amorphous Rock Phosphates, occurring in the Tertiary stratas—principally in France, Germany, and America (South Carolina).

Their commercial value is entirely based upon their strength in tricalcic phosphate, which ranges in some regions and for some markets, from 30 per cent. up to 85 per cent.

All those who are familiar with soil analysis will agree that, in the majority of cases, the phosphates therein are found to exist as

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phosphates of sesquioxide of iron, or alumina — insoluble in carbonic acid, but readily decomposed by the alkaline carbonates. We can therefore admit that, under the influence of a well-limed soil, or when acted upon by the carbonates resulting from the decomposition of the felspar rocks, these insoluble phosphates should yield their phosphoric acid, to be taken up in solution by water; either pure or charged with carbonic acid, and that in this form they should be absorbed with the water by the vegetable roots.

In the springtime, phosphates are found in noteworthy quantities in young organs of plants, especially in the leaves, but the quantity gradually diminishes as the plant approaches maturity, until when the blossoms appear, the phosphates are found to have entirely quitted the leaves and accumulated in the seeds. This is the cause of that peculiar effect, which has long puzzled farmers, that fodder cut and brought in *after the period of maturity*, proves to be much less nourishing to the cattle than that cut before this period has arrived.

It is worthy of note that in every instance, this displacement of the phosphates is accompanied by an equal displacement of the nitrogen, and all those who have made successive analyses of grains in different stages of maturity, must have been struck by the regular parallel manner in which the quantities of both have progressively augmented.

Mr. Corenwinder, in his work upon the migrations of phosphorus in vegetables, alluding to this phenomenon remarks:

"It has long been known that young buds are rich in nitrogenous matters, which are always accompanied by a relatively considerable portion of phosphorus, and there is no doubt that these two elements are united in the vegetable kingdom according to some mode of combination which is yet a mystery."

And Mr. Boussingault, writing upon the same subject, says:

"We perceive a certain constant relation between the proportions of nitrogen and phosphoric acid contained in foods, those being richest in the latter element which contain most nitrogen. This would appear to indicate that in the vegetable organization phosphates particularly belong to the nitrogenous principles, and that they follow the latter into the organization of animals."

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Now we have seen that nitrogen can, though in a very small degree, be really imparted to plants and to the soil from the atmosphere; and that after having assisted, through the plant, in forming the muscular tissues of the various animals, it is apt to reassume its aerial character and become at liberty to form fresh combinations either as ammonia or nitric acid. The *actual loss*, therefore, of this element is comparatively small; but with the phosphorus the case is a very different one, since it always maintains certain fixed combinations, and is taken away from and irrecoverably lost to the soil in immense quantities with every crop.

Hence the same question arises here which, as we have seen, arose in the case of the nitrogen, and none are more important or more worthy of profound consideration:

"How shall we restore to the ground those elements which we yearly take away from it?"

It will be our duty, later on, to point out the solution which science has furnished to this problem, and how the remedies it prescribes are to be employed with economy and profit.

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CHAPTER V.

POTASH: ITS ACTION ON THE SOIL —— IS IT ESSENTIAL TO PLANT LIFE? —— RESULTS OF DIRECT EXPERIMENTS —— ITS NECESSITY MADE CLEAR —— SOURCES OF ITS SUPPLY —— LIME —— THE LIMING OF SOILS —— ITS CHEMICAL ACTION —— ITS ABSORBING POWERS —— ITS ACTION ON SULPHUROUS ORES —— ITS ACTION ON IRON —— ALUMINA AND PHOSPHORIC ACID IN THE SOIL —— NECESSITY FOR ITS ABUNDANT USE.

The ashes of all plants, when submitted to analysis, are found to contain *potash* in noticeable proportion, and hence that substance is presumed to be a very active and essential fertilizing agent, although its precise influence in the process of development is not rigorously known.

It has been suggested that, once in the soil, it enters into a soluble combination with the phosphoric acid to form potassic phosphate, and in that shape becomes absorbed by the roots of the plants, the basic salt, however, remaining deposited in the various organisms after the evaporation of the water.

The doubts which have been expressed by many authorities as to the utility of introducing potash into the soil as an active artificial manure, induced Monsieur George Ville, when experimenting at Vincennes, to devote his particular attention to this disputed point, and although it cannot be said that his researches have added very much to our information from a chemical point of view, the results he obtained were of a sufficiently definite nature to warrant us in believing that the growth of plants would be unhealthy, if completely deprived of potash.

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On the one half of a completely exhausted field, plentifully manured with nitrogenous and phosphatic fertilizers, he caused to be sown a sufficiency of the finest quality grain. This sowing produced a crop of extreme poverty.

On the other half of the same field to which the same manure had been applied, but with the addition of potash, he sowed exactly the same quantity and quality of grain, and produced a crop of magnificent appearance and extreme abundance.

Exactly similar results have attended many experiments of our own upon plants of the leguminous species, and it therefore seems evident that due weight must be attached to the opinion of those who affirm that putting back potash into the soil, is quite as necessary in some cases as the addition in others of phosphate of lime.

We must not overlook that we have not yet penetrated into all the mysteries of plant life and plant feeding; that many things daily occur which overthrow or considerably shake the conclusions we had already formed and the theories we had built upon them; also that results obtained in some regions and by some agencies are often diametrically opposed in other places, although the surroundings appear to be the same.

We should, therefore, carefully guard ourselves against the adoption of those extreme views which have prompted some excellent chemists to teach us that potash has no merits as a manure, and which have induced others to assert that no perfect crops can be produced without its active intervention.

Joining our own experiences to those of many important agriculturists in France and England, with whom we have corresponded on the subject, we are content to endorse the opinions of George Ville; and to look upon the use of potassic salts as highly beneficial, if not indispensable.

The principal commercial sources of our potash are the mines of Stassfürt, Germany, where in the various forms of sylvine, kainit, and carnallite, it was discovered in 1858 in proximity to the beds of chloride of sodium (common salt). We generally meet with it as a

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tolerably pure muriate or chloride, and in this form recommend its addition to manures, or direct introduction into the soil.

If the utility and action of potash are sometimes contested, the same cannot be said of lime, than which few elements in agriculture play a more important part, or one that is better understood.

The liming of soils has been a common practice in all countries from the very earliest times; but it was presumably not until the seventeenth century that the use of *burnt lime* — now universally recommended — was introduced. It is employed in quantities varying with the composition and the requirements of a soil, from twenty tons per acre into those which are heavy, compact, and laden with moisture, to five tons per acre into those which are light and of a dryer nature.

That its scope of usefulness cannot be by any means guaged by the relatively small proportion found by analysis to exist in the plants, we must all agree, and we have often asked ourselves whether in point of fact, the presence of this element in plant organisms is directly connected with their nourishment and growth, or whether it is to be explained by the mere evaporation of the water by which it was conducted into the tissues and there deposited?

However this may be, the quantity absorbed *from* is out of all proportion to the quantity introduced *into* the soil, as will be seen from the following figures.

Quantity of Lime absorbed per acre by the undermentioned Cultivated Plants:

Potatoes,	Wheat,	Beetroots,	Clover,
7 lbs.	20 lbs.	18 lbs.	70 lbs.

And it is therefore not in this direction that we have to seek for its principal chemical action.

In certain regions pyrites, or sulphurous ores, are disseminated throughout the soils and underlying strata, sometimes in large but generally in minute quantities. The action of heat upon these sulphur-bearing substances generates sulphurous vapors, and these on meeting the elements undergoing the process of nitrification — already

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ready described — would form sulphuric acid, which, combining with the oxides in the soil to form sulphate of iron, would immediately render cultivation or vegetable growth impossible.

The counteracting or preventive part here played by lime is at once manifest, since by its ready absorption of the acid it would interfere with any other combination and become, itself, more soluble and efficacious by its transformation into gypsum.

Apart from such special cases as these, the virtues of lime must be attributed to its caustic action upon all organic remains.

Being rich in unavailable because insoluble forms of nitrogen, these are rapidly decomposed, and by coming in contact with other agents are submitted to the nitrification process and rendered assimilable; and this has given rise to the assertion that to spread lime upon a newly plowed cultivated field is equal to the application of a good dose of soluble nitrogenous fertilizer.

As we shall presently show, its intimate admixture in a finely powdered state with all kinds of clayey soils is invaluable, diminishing as it does their plasticity and augmenting their permeability to the action of air and water.

We have explained that phosphoric acid invariably exists in the soil in combination with peroxide of iron or alumina; these two agents must therefore exercise an immediate transforming action upon the phosphate of lime which is introduced in both natural and artificial manures.

This transformation can be demonstrated by adding either peroxide of iron or alumina, or both, to a solution of phosphates in water charged with carbonic acid gas (ordinary seltzer water at high pressure), when in a very short time all the phosphoric acid will have disappeared from the solution, and be found in the deposit as phosphate of peroxide of iron.

Now, if one gramme of this ferric phosphate be put into water with two or three grammes of carbonate of lime, and be allowed, with frequent shakings, to stand for forty eight hours — the mixture at the end of that time being poured into an excess of seltzer water —

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the solution will be found upon analysis to contain about six milligrammes of phosphoric acid.

The results of these experiments are too clear to permit of our doubting that the lime put into the soil becomes carbonate by its absorption of the carbonic acid gas, and that in this form it is chiefly instrumental in decomposing the phosphates of iron and alumina.

It is therefore necessary to furnish the soil with a considerable excess of lime, since if the free peroxides maintain the ascendant, no effect will follow the application of the phosphates, from the simple fact that their dissolution cannot take place.

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CHAPTER VI.

HOW SOILS LOSE THEIR NITROGEN —— TABLE OF PROPORTIONS —— NECESSITY OF SOIL ANALYSIS —— TABLE OF PHYSICAL ELEMENTS AND CHEMICAL CONSTITUENTS.

We have now reviewed the nature of the principal elements essential to vegetation, and have described the parts they severally play and the places they probably occupy in the organisms of plants. While admitting that, in some insignificant instances, we are still unable to completely unravel the mysteries connected with vegetable inner organisms, we may claim to be no worse off in this respect than the science of Pathology, to whose professors many secrets relating to the blood have still to be revealed. We have nevertheless been able to place on record a series of facts which support our theories and confirm our deductions ; and facts, as we are all aware, are "very stubborn things."

Thus, with man, it is not enough to give him food : his diet must contain a mixture of substances, the absorption of which is the condition of his existence, and whose composition is found to be identical with the materials constituting his bodily frame and tissues.

In plants the same phenomenon presents itself : deprived of certain elements they pine, droop, and die ; supplied with them they flourish and are vigorous ; and, upon analyzing their organism, we prove them to contain an abundance of the very elements without which they were unable to exist.

It will be interesting here to examine some figures showing us in what proportion the soil is regularly deprived by the different crops of its nitrogen, phosphoric acid, and potash.

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Table showing the approximate quantity by weight in POUNDS *of nitrogen, phosphoric acid, and potash, taken from the soil by every* TEN TONS *of the following crops:*

	NITROGEN.	PHOSPHORIC ACID.	POTASH.
GRAINS AND SEEDS.			
Wheat	520 lbs.	211 lbs.	138 lbs.
Rye	420	211	138
Barley	385	180	122
Oats	490	133	91½
Corn	405	135	81½
Colza	785	415	220
Linseed	810	320	257
Hemp	660	437	242
Poppy	650	420	184
Peas	850	221	260
Vetches	1010	202	160
Horse Beans	990	297	310
Lentils	900	135	205
Lupine	1380	221	293
FODDERS.			
Meadow Hay	335	96	410
White Clover	605	220	265
Red "	532	145	495
Luzerne	580	132	383
Vetche Hay	595	245	780
STRAWS AND STALKS.			
Wheat Straw	86	62	127
Rye "	62	46	197
Barley "	122	46	240
Oats "	94	52	197
Corn "	125	98	410
Pea "	265	98	271
Horse Beans	410	120	655
Colza "	79½	65	250
Linseed Stalks	192	116	300
Hemp	207	135	140
FLOWERS AND LEAVES.			
Hop's Cones	2235	237	568
Tobacco Leaves	1203	247	1368
ROOTS.			
Beets	46	31	98
Potatoes	84	46	142½
Turnips	52	35	82
Carrots	55	35	84

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No better arguments can possibly be adduced in favor of soil reconstitution, than the figures here given; for they seem to us to be a direct appeal from the plants themselves, for the administration of that food without which they must gradually starve and finally disappear.

We have, therefore, to study with increased earnestness that problem which has already been so long occupying the minds of agricultural scientists; the question of "how we are to arrest the marked falling off in the quantity and quality of our crops, by the impoverishment and gradual exhaustion of our soils; and how, where, and when we are to apply those elements of fresh vigor and life, which the discoveries of chemistry have placed at our command. When a man who has hitherto never been sick, finds that his health is beginning to fail, he, if possessed of common sense, calls in his doctor, who after careful diagnosis discovers the root of the evil and prescribes a remedy. Is it not evident that if he would know what to do for his soils to make them productive or amenable to culture, or to restore them to their past state of fertility, the farmer should first of all be made acquainted with their composition — their physical and chemical properties?

We have ever advocated the theory exposed at the commencement of this work, that no successful results can attend any attempts at scientific culture, if such attempts are made in ignorance of the elements we seek to improve; and for this reason we maintain that the only certain guide to successful cultivation, is the *complete chemical analysis of the soil, joined to a thorough knowledge of the climatological and other surrounding conditions.* With these at his command, the experienced chemist can throw the broad light of day on all the points which have been hitherto obscure, and can suggest methods of practical treatment, at once productive of a radical amelioration.

It has been and still is urged in some quarters, that no information procured in the laboratory, can be so perfect as that acquired by constant observation on the ground, and by continuous practical manipulation of the soil!

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We reply to this that, while quite prepared to accede in the very fullest manner to all the claims of long practice, and while admitting that some crops may be annually produced, it has frequently occurred in our experience that the addition of some essential element to the soil, discovered by chemical investigation to exist there in insufficient quantity, has been the means of immediately doubling the quantity previously produced of those very crops and greatly heightening their quality.

Thus, for example, it is very desirable to know how much lime a soil contains, since the different combinations which it facilitates or into which it enters, produce sweet, sound and nutritious green crops, full eared grain, and fine strong straws. If a soil contain too little or no lime, none of these advantages can accrue, and yet the farmer may have expended considerable sums in the purchase of other fertilizers, and will not comprehend their inefficiency until his attention is directly called to the absence of lime.

Again, it is necessary to know the proportion of combustible or organic matter contained in a soil, since upon their abundant presence depends the fixation of a greater or lesser quantity of nitrogen.

And yet again, there may be present some of those injurious compounds of iron or salt already described, or an excess of clay or of sand, or too much water, etc.

The whole of these cases, although of great importance, are merely elementary; for we must remember that in addition to them we require to know how much ammonia, nitric acid, phosphoric acid, potash, and many other elements a soil contains before we can form any just appreciation of its value.

Before proceeding to investigate the chemical constituents of a soil, it is, as we have seen, necessary to rigorously examine its *physical* properties, they being the real basis upon which everything subsequently depends.

No man in his right senses would attempt to build a house on moving sands, and just in the same way it would be futile to seek to introduce chemical elements into a soil, if it were found to be physically incompatible with vegetation and high-class culture.

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To ascertain the true physical and chemical condition of a soil, the following complete investigation must be undertaken :

Determination of its density or weight as compared with the weight of water.
Determination of its proportions of sand.
" " " clay.
" " " gravel.
" " powers of absorbing water.
" " " holding water.
" " drying capacity.
" " powers of absorbing solar heat.

These operations having been satisfactorily performed, and the physical properties thus accurately known, the study of its value for plant alimentation may be proceeded with in the following order :

Quantitative determination of its percentage of sulphuric acid.
" " " " nitric acid.
" " " " phosphoric acid.
" " " " nitrogen.
" " " " lime.
" " " " chlorine.
" " " " carbonic acid.
" " " " potash.
" " " " soda.
" " " " peroxide of iron.
" " " " alumina.
" " " " oxide of manganese
" " " " magnesia.
" " " " soluble silicates.

Armed with the results of this exhaustive investigation, we can at once find out how the soil may with rapidity and economy be brought to attain the highest degree of fertility.

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CHAPTER VII.

PHYSICALLY PERFECT SOILS —— STRONG AND LIGHT SOILS —— HOW TO AMEND CLAYEY LAND —— CLAY BURNING —— TREATMENT OF SANDY SOILS —— GREEN CROPS AS MANURE —— REMARKS ON DISINTEGRATION —— "FAIRY RINGS" —— THEIR EXISTENCE EXPLAINED —— HOW TO KEEP PACE WITH THE TIMES.

The most favorable physical conditions of a fertile soil are found to exist in a nearly equal mixture of sand and clay. When it contains less than thirty per cent., or about one-third of sand, it should cease to be classed among those fit for agricultural purposes, and, according to its composition, be turned to account in other directions. The two substances — clay and sand — are destined by nature to play respective parts, which may be thus described: the clay to store up and hold together those substances essential for plant food; the sand to serve as a ventilator or conductor of air and water.

As the defects of physically well-constituted lands may be easily discovered and dealt with by chemical analysis, our present purpose will be served if we devote our attention to those of a less happy nature, which, for convenience, we shall distinguish as strong or clayey, and light or sandy soils; the former being heavy, tenacious, plastic, and retentive of moisture; the latter porous and incapable of holding water. It not unfrequently happens that in some regions both these qualities are alternately met with in considerable abundance, extending over very large areas; and in such cases a judicious mixture is the natural remedy which suggests itself. In other regions we meet with vast tracts of land wholly

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composed of clay or entirely sandy, and here it is that our ingenuity must be brought to bear.

Commencing on a clayey soil with the removal of all excess of water, by a system of surface or substrata drainage, we must look around us for those substances which, by their addition, will communicate to the clay the necessary degree of porosity.

In a previous chapter we have explained that many surface soils have no natural connection with the rocks which underlie them; that they may have been carried to their present position, and deposited by water arriving from various distances, and that consequently they may cover strata of an entirely different composition to their own. An examination of this point, being very easily made, should never be neglected, because, if beneath the overlying clays we come upon beds of marls, limestones, or sand, we need seek no further for what is necessary to remedy the defects under consideration. Presuming, however, the non-existence of any underground source of improvement, recourse must be had to outside means: the application of cinders, furnace refuse, coal dust, or ashes, the ashes of all kinds of burnt vegetable refuse; old and discarded building materials, large quantities of lime, chalk, or marls; the whole of which will have the desired effect.

In some rare cases we have heard it objected that none of the bodies we have enumerated could be obtained in sufficient quantities, near enough at hand to admit of their employment; and that their transport from long distances is rendered impossible by the heavy and prohibitive charges for freight. Although such objections must soon disappear before the rapid growth of cheaper communications, we cannot afford to overlook them, but, bearing in mind that "*labor omnia vincit*," must seek and find in the clay itself a solution to the difficulty.

First roughly shaped into balls or bricks and allowed to dry in the sun, it should be burnt in small piles made up of alternate layers of clay, wood, coal dust, or any other cheap and readily available combustible material. When the burning process, which generally lasts some days, is terminated, the bricks or balls must be

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broken up as finely as possible, and, together with the ashes of the combustibles, plowed in a wholesale manner — deeply and thoroughly — into the field.

Our object in burning the clay is to make it undergo a radical chemical transformation, in the course of which it loses its water of combination and its power of absorbing and retaining moisture.

If, on the one hand, an excess of clay renders our agricultural operations so arduous, we find on the other that an excess of sand in the soil, and a consequent *lack* of clay, makes them impossible.

The most effectual method, therefore, of dealing with a sandy soil is to add to it a sufficient quantity of clay to hold together the fertilizing and nourishing agents, whether naturally present or artificially introduced ; for unless this is done, all the manurial elements (having nothing to retain them) will be washed from the soil by the rains and completely lost.

Where clays are not readily forthcoming, the use of marls and lime must be resorted to with an unsparing hand ; the latter accompanied with as much as possible of the green refuse — leaves, stalks, etc., etc., from the various crops.

It may even in special cases, and for a certain period, be advisable to use up all the lower orders of green crops entirely as manures for this kind of soil, in preference to keeping or selling them for food ; more advantage being likely to accrue from the beneficial action exercised by their decomposition than is represented by any momentary profit arising from their sale or consumption.

These vegetable substances should be very evenly distributed over the surface of the fields and plowed in simultaneously with the lime. Their beneficial effects arise not only from their power of retention, but also from their attracting and fixing the nitrogen in the air and the soil by the processes already described.

In considering all that has been written in the preceding pages upon the combinations and transformations that go on in the soils — their physical and chemical defects, and the means by which we are to remedy them ; and in examining that important question of manures which we are now about to open, there is one essential element

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in the conditions of success in high farming which we shall do well never to lose sight of. We refer to the necessity of maintaining the land in a fine workable condition by continually and thoroughly disintegrating, aerating, pulverizing and turning it over.

We have lengthily dwelt upon the oxidation and combustion of the organic matters, and the beneficial action of lime and other elements connected with their decomposition. We have shown how clayey soils may be made porous, and suggested means of rendering more tenacious and retentive those composed of sand. But in all these cases, unless the necessary means are adapted for breaking up the atoms and so finely dividing them as to make them accessible to the action of air and water — in other words, pulverizing the soil — what we have written would be deprived of more than half its value.

Now it stands to reason that certain portions of a good soil, and those most valuable because of their tenacity, will by the action of the rainfall become clodded; while others — the sandy and least retentive portions only — will remain in a state of separation or division. If, under such conditions as these, we introduce into the soil a costly manure containing either nitrates or ammoniacal salts, we shall find that those lumpy, hard and clodded portions, whose express mission it is to keep together and hold these elements in store at the disposal of the tender young rootlets, will not even receive them, and that with the very first application of water they will be washed away.

We have all seen — we see every day if we keep our eyes open — not only in our own fields, but in the fields of our neighbors, certain small delightful patches of a luxuriant vegetation, scattered here and there without any regard to order or regularity. The stalks are higher and stronger; the ears fuller; the grains larger and more plentiful; and the whole aspect of these "fairy rings" offer such a marked contrast to the other portion of the surrounding crop, as to irresistibly chain our attention and excite our wonder.

But no great genius is needed to discern the cause of this marvelous effect, which is simply a practical demonstration of two important facts:

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FIRST.—The undoubted efficacy of artificial manures, when well selected and judiciously applied.

SECOND.—That a badly worked soil, in a lumpy and imperfect state of division, is incapable of affording to the plants that amount of nourishment essential to perfect development.

Whenever we find it practicable, we recommend deep plowing; and, while filled with a becoming reverence for the memory of our grandfathers, we must deprecate the custom of too closely treading in their footprints. They were fain to rest content with the natural but only partial disintegration ensuing from exposure of the upturned clods to the atmospheric air; but we, let us remember, live in an age of progress and of rapid communication; and in agriculture, as in all other things, "the race is to the fittest."

If we would outrun — or even keep pace with — our competitors, we must watch and take lessons from the signs of the times, which teach us that we must increase our production and decrease our cost. In other words, we must make the lands produce their very best and largest crops, and in doing so must not only utilize our capital and our labor, but must freely exercise our brains as well.

The general practice now prevailing in Europe, of not only well pulverizing the soil after it has been plowed over and allowed to dry, but of repeating the operation at the time of adding to it the manure, and thus blending and mixing the whole, has been productive of the best results.

By following this course we shall attain a highly conditioned and sensitive soil, deriving in due season all the benefits of the rains, frosts, thaws, and solar heat; our manurial agents will be equally disseminated over an equally divided soil; and we shall thus not only render them doubly efficacious, but shall effect a large economy in the quantity necessary to be used.

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CHAPTER VIII.

PROGRESS OF THE MANURE TRADE IN THE UNITED STATES —— LOW PRICE *versus* REAL VALUE —— HOW THE FARMER IS SWINDLED —— BOGUS MANURES —— NECESSITY FOR ANALYSIS DEMONSTRATED —— HOW TO STAMP OUT THE EVIL —— ADVICE TO MANUFACTURERS.

To the questions: How are we to prevent the soils from becoming exhausted?—What must we do to increase rather than allow to diminish our yearly production? we have already foreshadowed our reply. Let us liberally return to the lands the equivalent of that which we have borrowed, and remember that our endeavors to get something out of nothing, will be like trying to squeeze a quart of liquid into a pint pot—sheer waste of time and ingenuity.

We have only to look about us to find out that the truth of our doctrine is already admitted; that it is rapidly gaining ground; that throughout the length and breadth of this vast country, earnest men are striving by experiment and example to root out existing prejudices. These missionaries are succeeding in their work, surely if slowly. We have the evidence of their success in the steady growth of the principal industries connected with the manufacture of fertilizers, of which the present annual production exceeds 500,000 *tons!*

What we have now chiefly to examine, therefore, is not so much the necessity of using manures—since that is admitted—as what kind of manures we are to use.

When a sensible man purchases a pair of boots, he tells his shoemaker he wants an article that will wear well, and that he is ready

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to pay a fair price for it. Sound quality is his first consideration. Why should not the very same idea predominate when we are buying a manure, and what is the invariable consequence of a contrary policy? In nine cases out of ten the "fertilizer" is but an abominable satire upon the name, and, having no other recommendation than its cheapness, produces no fertility. Its purchase is consequently the cause of a double loss: first, the money paid for its purchase, and second, the increase which would have accrued from the use of a good manure.

As a means of illustrating our meaning, we may here quote a case selected from hundreds which have come under our notice.

About three years ago, we were requested by a farmer in the south of France, to explain how we reconciled our theories with the facts resulting from his practical experience? He had made liberal and costly application of manures to his soils, and no increase or amelioration had taken place in his crops! Interrogated as to what manure he had been using, and what was the nature of his soil, he was totally unable to give any satisfactory reply; but informed us that he had purchased the material, prescribed and recommended by an agent who had called upon him, and that in doing so he had followed the example of many of his neighbors.

Upon examination of his soil, we found it to be of the poorest sandy character, composed as follows:

Moisture	1.80
Organic Matter	4.92
Oxides of Iron and Alumina	6.73
Phosphoric Acid	traces.
Carbonate of Lime	3.01
Potash	0.23
Magnesia	1.49
Sand and Insoluble Silicates	81.82
	100.00

Had we been consulted previous to the addition of any manure, we should have recommended, for growing cereals in such a soil as

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this, a good mixture of about equal parts of cheap cotton-seed cake dust and well made superphosphate, containing about 14 per cent. of soluble phosphoric acid — with the addition of, say, one-fifth of their combined weight of muriate of potash.

This mixture, well plowed in and thoroughly mixed, with a heavy top-dressing of slaked lime in fine powder, would not have failed to produce excellent results — considering the poverty of the ground.

An analysis of the manure actually used showed it to chiefly consist of valueless alkaline salts, sand, and earthy matters (probably a mixture of common poudrette and sand), minute quantities of nitrogen, and about ten per cent. of phosphate of lime; the whole with a very fœtid odor, to mislead the farmer, who has somehow an idea that no manure *is* manure unless it has a strong and characteristic smell.

This worthless mixture, foisted upon an ignorant man by a smooth-tongued rascal, was sold to him as phospho-guano, at the price of *thirty dollars per ton, in bags delivered at his farm*, and would have been dear at one-sixth of that price!

If agriculture is to remain the basis of the wealth of this country; if the United States are to ultimately become the greatest food producers for the world's teeming millions, there must be no such thing as exhaustion of the soil, or poverty in the crops.

The preventive remedies are known to us, and it rests entirely with ourselves to acquire them with certainty. On the one hand we know that an acre of fertile land should contain a certain percentage of phosphoric acid. On the other hand we have discovered that our own soil falls considerably short of the quantity required by the crops we desire to grow. We base our estimates upon the deficiency, and introduce a given quantity of superphosphate of lime.

The law says that, every trader in manures shall guarantee the genuineness of his wares by the test of chemical analysis. In other words, if superphosphate be sold as containing 12 per cent. of phosphoric acid, and be found to contain only half that quantity, the seller is deemed guilty of fraud and is liable to punishment. But

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can any penalty be proportionate to the enormous evil caused by this fraud, by which the farmer is robbed not only of his money, but of his time, his labor, his seed, the interest on his capital, and the rent of his unproductive land.

We are taught by an old adage that, "the wise rogue is the fool's natural parasite," and every day brings fresh instances of the folly and gullibility of mankind. Now, we do not agree with Carlyle in thinking that the majority of our rural population is composed of "mostly fools," and our system of education is gradually raising the standard of their intellect and intelligence, to a point which will soon leave the villages very little or nothing to learn from the towns.

Notwithstanding this, it is unreasonable to suppose that any class of men can suddenly overcome their old habits; discard their traditions; abandon as worthless all those methods which have been handed down to them through countless generations; and throw themselves into our arms without due reflection and perhaps some fighting. All great reforms have commenced with small minorities, and have had to struggle in the cause of truth, against prejudice, interest, and established custom, before being universally adopted. Is it not natural to expect that the great discoveries of scientific culture, should at first be sneered at and scouted by those who are unable as yet to understand them?

If the farmer will only take seriously to heart what we are trying to impress upon him; if he will only realize, once and forever, that the science of high farming is no longer a shadow but a living and indispensable reality, there will soon be an end to unproductive lands.

The States have placed at his disposal, and near to his hand, most excellent chemists, ever ready to advise and to assist him; he can therefore no longer plead ignorance in extenuation of any of his shortcomings.

A very trifling outlay, insignificant when compared with the importance of the result, will obtain for him all the information he requires: the composition of his soil, the elements in which it is deficient, and in what form those substances can best be introduced.

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When these points have all been settled, and when he has purchased his manure, chemistry will again step in and determine whether, in what he has bought, the necessary elements are actually contained.

We are all inclined, more or less, to be negligent even of our best interests, and we are satisfied that the majority of our farmers do not trouble to analyze the manures they purchase, but are fain to rely upon the promises and representations of the dealers. Alas! for the frailty of human nature! "*Opportunity makes the thief.*"

How many fertilizer mixers and dealers, are there in the world who are too high-souled to profit by this situation?

If once the custom of analyzing all purchased manures becomes a thing of course—looked upon as part and parcel of the commercial transaction; if once our farmers will take the trouble to ascertain the monetary value of all the ingredients employed in making manure, they will be able to distinguish what is good from what is worthless, and by ceasing to buy cheap "rubbish," will deal a death-blow at those miserable swindlers who trade in stuff which is "only made to sell."

The foregoing remarks are prompted by our strong desire to suppress an evil, the dire effects of which are so widespread as to indirectly strike at every interest.

If we are to have cheap food it must be produced in abundance!

How can it be produced in abundance if agriculturists are baulked in their efforts at improvement, and ruined by their purchase of materials which can give them no return?

The extensive sale of these so-called fertilizers under high-flown names, has done much to disgust those who have been victimized, with all ideas of progress, and has inspired them with such distrust of artificial manures, that, rather than make fresh trials and run fresh risks, they prefer to see their lands in a state of comparative sterility.

There surely must be—there naturally is—a large number of manure manufacturers in the United States of strict integrity and undoubted honor, and we would suggest to these, that they have a

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remedy against this evil in their own hands, which, better than any legislative measures, can at once stamp it out.

Let first-class manufacturers be of less difficult approach to the real consumers of their produce, and let them at once pass over the "middlemen" who find in adulteration such ready means of making profit. Let them now organize, in every region within reasonable access of their works, some kind of farmers' commercial club or "fertilizer syndicate" (?) with an energetic president and capable secretary. Let it be the duty of these two officials to discover and to tabulate the actual requirements of every member, in all kinds of manures, so that at proper seasons and in convenient time they may be manufactured in one batch.

Let some good chemist be chosen by the club on the one side and by the manufacturer on the other, and arrangements be made for contradictory sampling. Let the deliveries all be made at the same period, and allow the sampling to be performed in the presence of a chosen representative of the club, when the manure has been loaded and is ready for delivery.

Let analyses of each parcel be made by the respective chemists, and in case of a sensible difference between them, by a third chemist mutually agreed upon and whose decision would be final.

Let each member furnish to the club in some form agreed upon at a general meeting of their whole body, a suitable guarantee for the due payment *pro rata*, of the portion of manure supplied and invoiced to him by the club.

Finally, let the club itself arrange with its local banker, by a transfer of the securities which it has received, to guarantee the payment of the manufacturers' invoices in due season, say at four or six months, from the date of delivery.

The advantages of some such a system as this, appear to us to be very striking, and we feel certain that its adoption would be productive of mutual benefit and general satisfaction.

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CHAPTER IX.

THE DIFFERENT KINDS OF MANURE —— NOTES ON VEGETABLE MANURES —— ANIMAL PRODUCTS —— THEIR ANNUAL RECKLESS WASTE —— ESTIMATE OF THE LOSS TO AGRICULTURE —— HINTS ON THEIR PRESERVATION AND UTILIZATION —— GUANOS DESCRIBED AND ANALYZED —— THEIR VARIABLE QUALITY —— FISH MANURES —— TABLE OF NITROGENOUS SUBSTANCES.

A complete description and analysis of all the substances used as manure would of itself fill a considerable volume, but we doubt whether the advantage of such a treatise would be proportionate to the labor of its compilation.

We shall therefore confine our remarks to those of generally recognized utility, classing them as vegetable, animal, mixed (or farmyard), and mineral manures.

Vegetable Manure.

Every description of plant — roots, stalks, leaves and seeds — becomes, when plowed into the soil, a valuable fertilizing agent.

The most important, however, are those of the leguminous species, thanks to their long and trailing roots, by means of which they penetrate to a considerable depth into the earth, and thus acquire from below, elements which other plants are unable to attain.

From this reason the benefit of rotatory crops becomes manifest, and we understand at once why wheat crops are so much more plentiful, when following two or three crops of clover or luzerne.

The quantity of roots and stubble, or waste, from a crop of clover has been estimated to weigh, when dried at a normal temperature, one thousand pounds per acre. This would contain about fifteen

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pounds of assimilable nitrogen, and consequently be equal to nearly two tons of ordinary farm-yard manure.

Oil Cakes contain five per cent. of nitrogen and about three per cent. of phosphoric acid, with traces of potash. When damaged or otherwise unfit for cattle-feeding, they may be employed as manures with excellent results, especially on sandy or too porous soils.

In some districts near the coast, the sea weeds gathered along the shore are found to have a beneficial action, but as they contain a maximum of one per cent. of nitrogen and insignificant portions of phosphoric acid, we must consider their efficiency to solely arise from their slow carbonization or decomposition.

We have already dwelt at considerable length, in our previous chapters, upon the chemical action of vegetable organic matter on the various bodies contained in the soil, and it is only necessary to repeat here that in all cases where it is desired to grow cereals and to produce plentiful crops on an economical basis, the farmer will do well, rather than sell his green crops, to plow them into his wheat field as manures, and to plow them in evenly and with an unsparing hand.

Animal Manures.

Those within this category most worthy of attention are human dejections, guano, blood, fish, wool, rags, horns, hoofs, hair, and all animal refuse from the slaughter houses.

The efficacy of night-soil as a fertilizer has been recognized from time immemorial by practical farmers, but it is still more so now that the advancement of science has permitted us to accurately estimate its valuable elements, and to judge of the reckless manner in which they are yearly thrown away.

If we take the average weight of the entire population in the United States at ninety pounds each for men, women and children, we find that the daily product proportionate to this weight must not be less than two pounds per head.

The present population being estimated at fifty-five millions, we should reach the figure of fifty-five thousand tons per day, or, in round figures, twenty million tons per year.

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Taking the active principles to be in the proportion of 27 pounds of nitrogen and 6 pounds of phosphoric acid per ton, we can easily arrive at the annual total value by the following simple calculation:

27 + 20,000,000 =	270,000	tons nitrogen, at $50 per ton,	$13,500,000
6 + 20,000,000 =	60,000	" phosphoric acid, $30 "	1,800,000
		Net total value,	$15,300,000

It is a standing reproach to chemical science that we have not been able to devise a means of practically turning these vast agricultural necessities to account, and that because of our inability to conveniently store and render them inoffensive, our legislators are compelled to send them through the sewers into the sea.

All the attempts hitherto made to recover these substances from the sewage by means of precipitation have ended in failure, from the fact that chemistry has not yet discovered a method of effecting this precipitation, owing to the extreme solubility and volatility of the efficient constituents.

If these elements of fertilization are ever to be turned to good account in the proper channels for their employment, they must be kept out of the sewers, where they do immense harm by contaminating our drinking water and propagating diphtheria, and be submitted to some practical process of rapid desiccation.

The system by which these materials are turned to account in some parts of Europe, consists in allowing them to deposit in tanks, built for the purpose. In due course the supernatent liquid is decanted off and used for the manufacture of sulphate of ammonia; while the solid portion is dried up by the addition of slaked lime, and sold in bags under the familiar name of *poudrette*.

A good sample of this manure, lately submitted to us for analysis, was found to contain forty-eight per cent. of organic matter, two and one-fourth per cent. of nitrogen, six per cent. of phosphoric acid and ten per cent of lime; and would doubtless be productive of very excellent results in the field.

Wherever such operations are practicable, we strongly recommend all farmers to build small tanks in various portions of their

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ground. These tanks should be about five feet square and six or seven feet in depth, and must be carefully lined with good Portland cement. Into these tanks should be thrown the whole of the night soil collected in the neighborhood; care being taken to keep them well covered by nicely adapted wooden lids, and to exclude the entry of water. The occasional addition of finely powdered slaked lime will assist the drying and effectually destroy all smell.

Guano.

No name is more widely and generally known, even to the smallest child, than that of this popular fertilizer, and although it has served for many years as a cloak to swindlers of every kind, who have sold under its name piles of worthless trash, farmers cannot forget their old affection for it.

There can be no doubt that, for a considerable length of time after its introduction, very marvelous effects followed the application of this manure, but the enormous and continual drain upon the production, and the never-varying result of speculation and jobbery, would seem to have told a tale upon it, and the quality is now of a very variable nature, with a tendency to become more and more so, as time goes on.

The principal sources of supply are Peru, Chili, Bolivia and the South Sea Islands; and the deposits proceed from a species of sea fowl known as *Guanaes*, which feed upon the small fish that literally swarm the waters near the coast.

The high percentage of nitrogen contained in the Peruvian shipments of former years, must be attributed to the absence of rain, which characterizes that country; those arriving from other regions having lost a considerable portion of their ammoniacal salts through the action of water.

The trade in Peruvian guano is monopolized by the Peruvian government, and the immense deposits sometimes attain a depth of one hundred feet.

This latter fact has induced a great deal of controversy as to the period from which we should date their commencement, some author-

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ities being of opinion that it must necessarily be before the deluge.

In his very able book upon the subject, Mr. F. de Rivero advances some skilful arguments to prove that they are of more recent date; and, basing his calculations upon the existing quantity of about 20,000,000 tons, he says:

"Presuming the constant presence of only 264,000 of these birds, (and I am perfectly convinced there is nothing at all exaggerated in these figures), supposing each bird to furnish but *one ounce* of manure in every twenty-four hours, we easily arrive at the figure named, in a period of between five and six thousand years."

The value of real guanos from all sources is estimated upon the basis of their nitrogen, ammonia, phosphate and organic matter, and when of sound quality they have generally realized from $65 to $70 per ton.

The following are the analyses of two cargoes purporting to be of the same quality and shipped from the same port at the same time, arriving in London at the commencement of 1882:

PERUVIAN GUANO.

	CARGO No. 1.	CARGO No. 2.
Moisture	16.00	15.28
*Organic Matter, Salts of Ammonia	52.50	14.72
Phosphate of Lime	19.52	33.12
†Phosphoric Acid	2.12	traces
Alkaline Salts	8.00	8.93
Insoluble and Sandy Matters	0.86	27.95
	100.00	100.00
*Nitrogen	15.30	2.70
†Soluble Phosphate of Lime	6.76	none

As these are far from being exceptional instances of the great uncertainly of these products, we feel compelled—while admitting that no better manure than *good* guano is to be found—to advise the discontinuance of their use, and the employment of well-made chemical substitutes, until shippers *guarantee them* to contain a stipulated *minimum* percentage of the active principles.

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Fish.

The refuse of all kinds of fish afford sources of the richest and most desirable kind of manure, and it is unfortunate that some wholesale and cheap method of popularizing it has not been forthcoming. When cooked, deprived of its oil and water by heavy pressure, and thoroughly dried, it is easily reduced to a fine powder, of which the following is an average analysis:

Moisture	1.30
*Nitrogenous Organic Matter	78.01
Alkaline Salts	5.30
Chloride of Sodium	Traces.
Phosphate of Lime	15.00
Magnesia	0.33
Carbonate of Lime	Traces
Insoluable Siliceous Matter	0.06
	100.00
*Equal to Nitrogen	10.00

Blood, Wool-Refuse, Hair, Hoofs, Horns and Offal.—All these are valuable sources of nitrogen, and in some cases may be economically and beneficially employed. They call for no special mention and are nearly all old friends of the agriculturist. We append a list of sundry materials showing their approximate percentage in assimilable nitrogen, which may not be without utility.

Table showing the quantity of nitrogen, in pounds, contained in every one hundred pounds of the following substances:

			Nitrogen.
100 pounds of		Shoddy contain	7½ lbs.
100	"	Wool Dust contain	9½ lbs.
100	"	Dried Blood contain	12 lbs.
100	"	Rape Cake contain	5 lbs.
100	"	Cotton Cake contain	5½ lbs.
100	"	Sugar Scum contain	3 lbs.
100	"	Glue Refuse contain	2½ lbs.
100	"	Leather Cuttings contain	8 lbs.
100	"	Crude Ammonia contain	7½ lbs.

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CHAPTER X.

FARM-YARD MANURES —— COMPOSITION OF THEIR LIQUID AND SOLID ELEMENTS —— COMPARATIVE VALUE OF ABSORBENTS, WITH ANALYSES —— COMPOSITION OF VARIOUS STRAWS —— SUPERIOR VALUE OF THE LIQUID SUBSTANCE —— HOW TO PRESERVE AND UTILIZE IT —— TREATMENT OF MANURE HEAPS —— HOW TO COMPLETE THEIR VALUE AS FERTILIZERS —— THEIR DECOMPOSITION —— FORMATION AND DESCRIPTION OF HUMUS —— EXPERIMENTS ON FRESHLY MADE AND FERMENTED MANURES —— RESULTS OF EACH EXPERIMENT —— GENERAL REMARKS.

In entering upon an examination of what is perhaps the most important matter with which we have had to deal, we shall carefully avoid all ideas of prejudice and partiality.

None of us ignore that farm yard manures have for many centuries been the prop and mainstay of our agricultural operations, and no science was necessary to teach us that it owed its virtues to its happy combination of physical and chemical constituents.

If it were possible for those who cultivate old or mature soils to manufacture a sufficiency of this manure, the introduction of chemical substitutes would in their case be unnecessary, and the problem which is occupying our attention would never have arisen.

The requisite quantity to constitute complete restitution could, however, be only attained by literally putting back the whole of the crops and living things which have derived direct and indirect sustenance from the soil; and hence, even if such an idea were not absurd, it would be impracticable, since the grains, seeds, cattle, poultry, milk, butter and wool, are all sent to market and go to feed the teeming populations of the towns.

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Such manures as we are able to gather up in and about our farms, from all sources, may consequently be considered as the mere excess taken from the soil by the crops gathered in, and would certainly not suffice of themselves to stay the already marked impoverishment and eventual exhaustion which must naturally be the effect of such a comprehensible cause.

We may, therefore, consider the employment of chemical and artificial fertilizing matters, as not one whit less necessary in places where an abundance of offal appears to exist, than it is in other circumstances where there is very little or none at all, and the liberal employment, judicious selection and economical purchase or manufacture of sound manurial materials is the fundamental condition of successful high farming.

We must consider it a matter of very third rate, if of any importance to us, whether a manure is vegetable, animal, mineral, natural or artificial, having merely to assure ourselves by chemical analysis that it contains the needful elements, and that by its employment we can increase our crops and enhance our profits.

The value of stable dung must not be estimated upon its actual richness in ammonia or phosphoric acid within a short period of its production, but must be calculated on its wonderful physical and chemical action on the elements of the soil and the air, and upon its merits as a vehicle or conductor into which completing quantities of outside substances can be introduced, decomposed, and rapidly made available.

The composition of its different constituents may here be set forth in the following order:

Analysis of various kinds of Stable Urine.

	Sheep	Horses	Oxen	Goats	Pigs
Water	96.40	90.50	91.40	98.20	98.20
*Organic Matters	1.00	5.50	5.50	0.90	0.50
†Alkaline Salts	2.60	4.00	3.10	0.90	1.30
	100.00	100.00	100.00	100.00	100.00
*Containing Nitrogen	1.70	1.75	1.50	traces	minute quan.
† " Phosphoric Acid	traces	traces	traces	traces	traces

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The quantity per head yearly produced of this liquid may be estimated at:

For Cows	Four to Five Tons.
" Horses	Three to Four Tons.

Analysis of various kinds of Solid Excreta.

	Sheep	Horses	Oxen	Pigs
Water	68.71	78.36	79.72	75.00
*Organic Matters	23.16	19.10	16.04	20.15
†Alkaline Salts	8.13	2.54	4.24	4.85
	100.00	100.00	100.00	100.00
*Containing Nitrogen	0.72	0.55	0.32	0.70
† " Phosphoric Acid	1.52	1.22	0.74	3.87

The result of many investigations of the mixed matters above detailed, prove them to contain in every hundred pounds rather less than half a pound of nitrogen and about two pounds of phosphoric acid.

The collection, absorption, and association of the liquid with the solid matters, being the most important factor in the manufacture of an efficient product, it is in all cases advisable to use abundant quantities of cereal straws for littering or bedding, in preference to any other material; they having been found to possess the greatest possible capacity for holding moisture, as indicated by the following figures:

Table showing the powers of absorbing water in 24 hours, by every 100 pounds of the following kinds of straws, as compared with those of other substances.

Wheat Straw absorbs	110 pounds.
Barley " "	285 "
Oats " "	228 "
Colza " "	200 "
Corn " "	162 "
Marl absorbs	40 "
Dry vegetable soil absorbs	50 "

The chief active principles which form the composition of cereal straws and other vegetable matter, commonly used for bedding in

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stables, have been ascertained to be the following: the quantities shown in the table being those contained in every 100 pounds, by weight of the substance analyzed.

	Ashes	Phosphoric Acid	Nitrogen
Wheat Straw	3.51	0.25	0.24
Rye "	2.79	0.15	0.17
Barley "	5.24	0.20	0.23
Oats "	5.75	0.21	0.28
Corn "	4.00	0.86	0.19
Colza Tops	3.85	0.36	0.75
Vetche "	5.10	0.28	0.10
Bean "	3.10	0.22	0.20
Pea "	5.00	0.59	1.79

We have very frequently observed that in the minds of some farmers — producers of large quantities of stable offal — the prevailing idea is, that the solid portions are those really valuable, and that the liquid may be neglected and abandoned. Our great object in giving the above analyses, is to impress upon such men as these the utter fallacy of their opinions, and the necessity for their immediate reform, and to persuade them that they are continually making serious losses by the waste of this precious fertilizer.

We suggest the adoption of a good system of drainage in every stable, the flooring of which should be upon a slight incline to allow the liquid to pass off with facility, by means of underground pipes made if possible from good refractory clay. The urine should be conducted to tanks or reservoirs, of a similar nature to those already recommended in a previous chapter, and be kept well covered over; these tanks should be connected with a pump, by means of which the liquid could frequently be made to saturate the forming heaps of manure, thereby serving to steady and regulate the fermentation or process of combustion going on within.

If due weight is attached to those points, they will produce the double advantage of increasing the quantity of ammonia contained in the ultimate manure, and of decreasing the risk of contaminating the wells or springs made use of by the cattle, if not by the population of the neighborhood.

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The solid portions and the saturated straw should be allowed to remain under the cattle as long as is consistent with health and convenience. And when forked up should be carefully mixed and deposited in uniform layers upon the heap; care being taken to break up and disseminate all lumpy portions, before the application of the liquid by means of the pumping process above described. The very highest possible results will be obtained if, from the commencement of each heap, the habit is contracted of regularly adding to each layer, as it is put on, a certain evenly distributed quantity of some artificial manure, the nature of which will be dictated, and vary, according to the wants of the soil and contemplated crops.

Supposing a high grade phosphatic material combined with potash to be necessary, nothing could be better than the addition of a good, soluble, ten or twelve per cent. superphosphate of lime, and muriate of potash, in the proportion of twenty-five pounds of the first and ten pounds of the second, to every hundred pounds of manure. Whereas, if nitrogen is the element required to preponderate, the introduction into the compost of wool refuse, leather scraps, glue refuse, blood and other offal, collected from the various dealers, manufacturers and slaughter-houses, in the nearest towns is highly recommended.

The chemical transformations or reactions which go on in the compost heaps during their fermentation, are of too complex a nature to be fully described within the limits we have prescribed for ourselves, nor is its precise knowledge of any necessity for practical purposes.

We shall therefore rest content with explaining that a process of slow combustion or carbonization very soon sets in, and serves to maintain a temperature of about 100° to 105° Fahrenheit. The air within the mass being composed of carbonic acid and nitrogen gases, with traces only of oxygen.

By making a clean incision in such a fermenting manure heap as we have described, through the centre from the top to the bottom, we shall find that while the straw at the surface maintains its normal appearance, it gradually assumes a dark brown color towards

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the middle and is altogether lost lower down, in a black slimy mass of decomposition called *humus*. This body is formed under the influence of atmospheric oxygen by the union of certain elements contained in the straw or vegetable matters, with the ammonia emanating from the fermenting animal matters urea, uric acid, etc.

That the presence and intervention of these vegetable elements is indispenable to the preservation or fixation of the generating nitrogen, is demonstrated by the fact that, if the animal matters were left to ferment by themselves, this element would rapidly change into the phosphate, thence into the benzoate, and finally into the carbonate of ammonia, in which form it would immediately volatilize and be a total loss.

Humus therefore not only changes this volatile carbonate into a fixed and staple product, but possesses the faculty of absorbing and retaining fresh nitrogen from the air and rendering it assimilable when transferred to the soil.

We hope that by these explanations we have impressed upon farmers the necessity of allowing their farm yard manures to undergo a thorough process of fermentation, and to completely rot or carbonize before making use of them in the field, and in order to make our meaning still more clear, let it be remembered that :

A.—If freshly made manure be put into the soil, the saline and nitrogenous portions will all be washed away by the first fall of rain, and lost.

B.—If the manure be allowed to thoroughly ferment, the nitrogenous matters will remain insoluble in the soil, and will thus be held at the disposal of the plants ready for assimilation.

A series of very interesting experiments upon the laws laid down by the illustrious Paul Thenard, were recently made by ourselves, in verification of these assertions, with the following results :

The drainings from a field near Leeds, in Yorkshire, liberally dressed with freshly made manure, were submitted to careful analysis after a heavy shower of rain, and found to contain noteworthy quantities of nitrogenous matters.

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After publishing the complete results of these experiments, we were enabled to collect the drainage from a large field in Portsmouth, Hampshire, which had been thorougly dressed with completely fermented manure, and in this case the water was found to bear mere traces of ammonia or nitrogenous substances.

A few experimentors have striven within the past few years to persuade themselves and the world that the total abandonment of farm yard manure, and the sole employment of chemical fertilizers, would result in immense economy and increased production; but in nearly every case within our knowledge, where the seduction of these theories has prevailed over common sense, the result has been, to say the least, discouraging.

That artificial manures of every kind are necessary, we have always admitted and shall always propound ; that as supplements in all cases, and substitutes in some, their constant employment is naturally indicated, we readily agree ; but that they can ever profitably and usefully replace those made on the farm either physically or chemically, is a proposition, to our minds, too ridiculous to merit discussion.

When due care has not been taken in their preparation and treatment, their actual and normal percentage of ammonia may be slight, and their *value*, from that standpoint, insignificant ; but even then, (and we are taking them at their worst), if their fermentation has been complete, and their rapid oxidation assured by thorough plowing in and frequent turning over in a well-conditioned soil, no artificial nitrogenous fertilizer can ever be compared to them for economy and proportionate efficacity.

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CHAPTER XI.

MINERAL MANURES —— BONES AND WHAT THEY TAUGHT US —— SULPHURIC ACID AND NITRATE OF SODA —— BONE ASH —— ANIMAL CHARCOAL, OR BONE BLACK —— BONE MEAL —— SULPHATE OF AMMONIA —— ITS GREAT POWER OF DECOMPOSING OTHER MANURES —— HOW TO DETECT IMPURE NITRATE OF SODA —— NITRATE OF POTASH, OR SALTPETRE —— PHOSPHATE OF LIME —— RIVER PHOSPHATES —— CANADIAN PHOSPHATE —— A RIDICULOUS EXTORTION.

We have now to undertake the examination of those mineral fertilizers which come next in order, and which form the staples of that great and advancing industry, chemical manure manufacture.

For the sake of comprehensiveness and brevity, we propose to divide our subject in the following order :

FIRST.—A hasty glance at the principal sources and the agricultural value of phosphatic and other raw materials of a mineral nature, with analytical tables showing their composition.

SECOND.—A description of the principal sources of sulphur pyrites, and of sulphuric acid and superphosphate manufacture, with brief notes on the mixing of various compound manures.

As we have already roughly described, in a preceding chapter, how mineral phosphates are found in nature, we need merely refer our readers to the particulars there given, and at once attack the practical question before us.

BONES are a very old and very favorite manure, and it is to their employment and to the researches ensuing upon their marked effect that we owe our discoveries relating to the part played by phosphoric acid in the soil.

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Their extensive use in the manufacture of phosphorus has, however, so much enhanced their commercial value, that we may look upon them as beyond the reach of the agriculturist.

When dissolved in sulphuric acid and mixed with nitrogenous materials, or farm-yard offal, to form complete manures, they may be considered as occupying the very foremost place in the order of merit as fertilizing agents.

They are frequently used with nitrate of soda, in the raw crushed state, as a dressing to sandy soils and pasture lands; but we have personally found their action in these cases to be very slow, and their assimilation a work of time, so that we cannot recommend a continuance of the practice.

Bone Ash results from the burning of bones and is chiefly exported from the cattle-raising districts of South America, where, fuel being scarce, the bones are burnt in the process of extracting the fat from the slaughtered oxen.

Animal Charcoal or Bone Black is justly esteemed by all those who are fortunate enough to obtain it on reasonable terms. It is an excellent absorbent, and is extensively used in sugar refineries, being only delivered to agriculture when it has lost its powers of discoloring the juices.

Bone Meal is the impalpable powder of bones, from which a steam process has succeeded in extracting all the gelatine.

The following table shows the general composition of these materials :

	Crushed Bones.	Bone Ash.	Bone Meal.
Moisture	6.94	2.18	5.27
*Organic Matter	36.93	6.43	17.15
Phosphate of Lime	48.26	69.95	68.02
Carbonate of Lime and undetermined Mineral Salts	7.46	14.01	9.16
Insoluble Matter	0.41	7.43	0.40
	100.00	100.00	100.00
*Containing Nitrogen	3.72	Traces.	1.58

Sulphate of Ammonia is largely obtained from animal urine, but chiefly from the ammoniacal liquor derived from gas works

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after the purification of gas. These liquors are mixed with fresh slacked lime and forced to the top of small towers, into which are fitted a series of trays. The liquid flowing over the edges of these trays in a succession of small cataracts, is met and traversed by a column of steam, which during its ascension, deprives it of all its ammonia.

The steam thus charged is conducted to a coil of perforated pipes in a tank of sulphuric acid, to which, as it passes through, the ammonia is yielded up.

When the acid is fully saturated, it is led into another tank and allowed to settle, and finally is subjected to a process of hot concentration to effect the crystallization of the sulphate of ammonia. This salt has the form of white or greyish transparent crystals, is sharp and bitter to the taste, is soluble in twice its weight of cold water, and contains an average of twenty-one per cent. of nitrogen.

We have before alluded to it as an invaluable source of nitrogen, and this, although sufficient, is not the only virtue for which it recommends itself.

Our own experiments induce us to believe that when introduced into the soil, the sulphuric acid set free by its natural transformation, largely assists the decomposition of all surrounding organic remains, and transforms any phosphoric acid that may be present into acid or soluble phosphate.

NITRATE OF SODA is a natural mineral, principally found in Chili and Peru, and shipped from Iquique. It occurs in large beds, several feet thick, intimately mixed up with sulphate, chloride, iodide of sodium and many other bodies, and when in this state is known in commerce as *caliche*, or crude nitre, of which the following is a typical analysis :

Nitrate of Sodium	63.92
Sulphate "	4.01
Sulphate of Lime	Traces.
Sulphate of Magnesia	Traces.
Chloride of Sodium	28.32
Iodide "	.76
Insoluble Matter	2.99
	100.00

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After having undergone the refining process, it contains 95 per cent. of pure nitrate of soda, and 14 to 16 per cent. of nitrogen, and is then found to be a highly stimulating manure for grass-growing in meadow lands.

In consequence, however, of its very high price, it is frequently, if not generally, the object of adulteration, and should, therefore, never be purchased from any but respectable firms with a written guarantee of its analytical contents. Even when this is obtained, it should not be employed before its genuineness has been ascertained, and the following rough but sufficiently accurate test can be applied by every farmer, when no chemical laboratory is near at hand.

A small portion of the nitrate is to be mixed in a tea cup with sufficient oil of vitriol (sulphuric acid), to just cover it, when, if a copious quantity of greenish, suffocating vapor be given off, it will be evident that the article contains a large proportion of common salt, this being, from the similarity of its appearance, the adulterant generally used.

Nitrate of soda plays a very leading part in the manufacture of sulphuric acid, as will be seen later on, being used in the proportion of about 5 per cent. of the weight of sulphur consumed.

The fact of its costing from fifty to sixty dollars per ton, renders the question of its economical application one of the most difficult with which manufacturers have still to deal; and there are unfortunately many works where, owing to unskillful manipulation, instead of *five per cent.*, double that quantity more correctly expresses what is used or wasted.

Supposing, therefore, that in an acid works which burns 2,000 tons of sulphur per annum, in any of its forms, 10 per cent. of nitrate is consumed, we may fairly consider that there is an unnecessary waste of 100 tons of nitrate of soda, and this at $50 per ton represents a yearly dead loss of $5,000.

There are a great number of our sulphuric acid manufacturers who do not give this matter sufficient attention, and who, consequently can make no real profits on their acid productions.

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NITRATE OF POTASH, commonly called saltpetre, is industrially produced by the double decomposition, resulting from a mixture of nitrate of soda and muriate of potash, with the application of heat. Commercial saltpetre contains 10 to 12 per cent of nitrogen and from 40 to 44 per cent. of potash.

It is soluble in three times its weight of water at an ordinary temperature.

MURIATE OF POTASH is, as we have already pointed out, the best form in which to introduce potash, either directly into the soil, or as a constituent in a compound manure.

When freed from its chloride of sodium, sulphate and chloride of magnesia, which always accompany it, the salt contains from 45 to 48 per cent. of pure potash.

It is soluble in five times its weight of water, and has a salt and bitter taste.

PHOSPHATE OF LIME.—The most readily accessible materials for consumption in the United States, are the phosphorites of Charleston, South Carolina, and the apatites, or crystallized phosphates, of Canada.

The phosphorites of the Charleston basin occur in the form of nodules, bedded in the clay and sand. They cover an immense area, and are found in detached deposits, at irregular intervals, all along the water-courses of the country; through the swamps and on the banks of the rivers and streams.

They are generally irregular in form and color, being partially rounded by the action of water, and of a yellow, green, or brown; while fossilized remains of fish are always, more or less, intimately mixed up with them.

They are distinguished in commerce by the names, Land and River phosphates — the first being the softest and lightest colored.

They are dug up and submitted to a washing process, which frees them from nearly all the sand and clay, and when thoroughly dried after this operation, are ready for grinding, and present the following average composition:

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	1	2	3
Moisture	4.89	3.10	7.89
Water of combination	2.01	1.55	1.57
*Phosphoric Acid	25.60	23.33	22.10
Lime	37.19	36.02	37.18
Magnesia	0.75	0.80	traces.
Oxide of Iron and Alumina	9.16	8.70	10.02
Carbonic Acid	4.09	5.00	3.97
Sulphuric Acid	1.77	2.00	By difference 5.15
Chloride of Sodium	2.03	1.97	
Fluorine and loss	2.22	2.14	
Insoluble and Sandy Matter	10.29	15.39	12.12
	100.00	100.00	100.00
*Equal to Tribasic Phosphates of Lime	55.80	50.85	48.17

The river phosphates are generally of a somewhat higher percentage than the above, and now furnish the bulk of our supply. They usually contain minute quantities of iron pyrites, are of a dark gray, nearly approaching to black color, and are extremely hard and difficult to reduce to an impalpable powder.

When dried and ready for shipment the general average result of their analysis is the following :

	1.	2.	3.
Moisture	0.62	0.71	0.56
Water of combination and loss on ignition	3.09	1.27	2.80
*Phosphoric Acid	29.03	27.30	25.33
Lime	45.27	39.22	39.20
Magnesia	Traces.	0.35	0.27
Oxide of Iron and Alumina	9.10	9 36	10.15
Carbonic Acid	3.34	3.18	2.70
Sulphuric Acid, Chloride of Sodium, Fluorine, By difference	3.42	6.70	4.79
	6.13	11.91	14.20
Insoluble Sandy Matters	100.00	100.00	100.00
*Equal to Tribasic Phosphate of Lime	63.28	59.50	55.20

They are mined from the rivers under concessions from the government, in consideration of certain royalties paid into the State coffers, for every ton extracted and taken away.

The deposits are very extensively worked throughout the entire year, but most energy is displayed during the summer months, when they afford employment to thousands of work-people.

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The dredging apparatus ordinarily employed is fitted with washers which effect the separation of the phosphate from the sand and other extraneous bodies, while being raised through the water.

Both qualities of these phosphates, when finely ground, afford an excellent material for superphosphate manufacture, despite their somewhat heavy percentage in iron and alumina, and their large pro portion of insoluble matter.

As they contain very little carbonate of lime, their treatment entails no waste of sulphuric acid, and they possess the superiority over many other phosphates, when properly decomposed, of yielding up all their phosphoric acid in a soluble form.

CANADIAN PHOSPHATE occurs in the form of bottle-green crystalline masses, more or less associated with portions of the gneissic rocks or mica slates which surround it in its native fissures. It is in all respects a mineral, and is found in clearly defined veins and cavities, extending sometimes to a very considerable depth, and becoming richer in their yield as they go down.

The following analyses are fairly representative of its general composition, and have been selected from many hundreds made by ourselves and differing only in trifling details:

	1	2	3
Moisture and Water of combination	0.09	0.13	0.59
*Phosphoric Acid	41.13	37.63	35.28
Lime	53.70	50.95	47.19
Carbonic Acid	1.37	1.60	1.18
Sulphuric Acid	traces	0.26	traces
Oxide of Iron	0.06	1.12	2.51
Alumina	0.54	0.96	3.60
Magnesia	traces	traces	traces
Fluorine	2.14	4.07	5 30
Insoluble Siliceous matters	0.97	3.28	4.35
	100.00	100.00	100.00
*Equal to Tribasic Phosphates of Lime	89.65	82.05	76.90

When pure it is a fluor-apatite, composed of phosphate of lime and fluoride of calcium, and is generally presented to commerce in the rough, in blocks varying in weight, from one to several hundred pounds, of a beautiful green color and brittle texture.

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It is, however, as the foregoing analyses show, not very frequently met with in a high state of purity, but generally contains certain portions of iron and alumina, besides being mixed up with quantities of an inert kind of gangue, from which its separation (by hand work) is arduous and costly.

These phosphates are extremely hard and difficult to grind, and may be said to contain no carbonate of lime. Their percentage of iron and alumina is not sufficiently high to militate against their satisfactory decomposition, but what causes them to be regarded with disfavor, is their variable, but always considerable proportion of fluorine, which, upon being brought into contact with sulphuric acid in the manufacturing process, generates large volumes of most irritating and poisonous vapors of hydrofluoric acid.

The great inconvenience and danger arising from this cause, can only be obviated by bringing the acid to bear upon the mineral and effecting its decomposition, in well-closed mixers. If these mixers are provided with proper ventilating shafts, to carry off the gases as soon as they are set free, no cause for apprehension will any longer exist, and the material will yield the most satisfactory results,

A large majority of manure producers in this country have, however, hesitated to make the needful changes in their plant, and have preferred the use of South Carolina phosphates, as offering much less difficulty from an industrial, and yet excellent results from a commercial point of view. In consequence of this policy the greater portion of Canadian apatites have always been, and still are, shipped to England, whence they very frequently come back to America as superphosphates of lime. It is to be devoutly hoped that the rapid progress now being made in all the arts throughout the United States, will shortly induce the larger manufacturers to reconsider their policy and make more use of this excellent and high grade phosphate.

Why should American farmers bear the enormous loss represented by the cost of freight from Montreal to English ports, and from thence back again to their own ; amounting in the aggregate on the manufactured article to a total of seven or eight dollars per ton ?

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If the use of chemical manures is to become a universal institution and a "thing of course," they must be placed within reach of consumers, at the lowest possible price; because, were the maintenance or increase in the quantity and quality of our crops to be simply counterbalanced by the cost of the fertilizers, no ultimate advantage could accrue from their application.

The mixture of finely powdered raw phosphates with farm-yard manures, in a manner similar to that pointed out in our last chapter, is productive of excellent results. And their direct application in the same raw state to lands of which the soils contain an abundance of sulphuric, humic, carbonic, or acetic acid, is also very successful.

In each case, however, an impalpable state of powder and extreme state of division in the soil are absolutely indispensable.

Although the principal sources from whence phosphates can be most economically obtained in this country are those just dealt with, it will be interesting for the sake of comparison, to introduce a table of analyses of the different qualities and forms produced and used throughout the world. (See page 66.)

It will have been noticed that in all cases the chemical value of these bodies is determined by their percentage of phosphoric acid, and it is therefore advisable to here set forth an approximate translation of the scientific formula by which the composition of a phosphatic body is ascertained.

The substance destined for examination is first treated with boiling nitric or muriatic acids, which dissolve all its active ingredients, the parts remaining undissolved being composed principally of sandy and siliceous matter.

The phosphoric acid, lime, iron, alumina, etc., etc., are all contained in the acid solution and are withdrawn from it and estimated, by adding to it other substances for which they have strong affinities, and with which they form insoluble salts. For example, if we add oxalic acid and oxalate of ammonia, they will immediately combine with the lime, to form oxalate of lime, and in that state will fall to the bottom of the vessel.

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Table showing the general composition of the most important phosphatic materials used in agriculture and chemical manufactures, not already described:

	Spanish and Portuguese.	Navassa.	Aruba.	Curacoa.	German.	French Bordeaux.	French Ardennes.	Mexillones. Guano.	Cambridge Coprolites.	Norway Apatites.	Russian Coprolites.
Moisture	1.20	5.73	5.53	0.75	1.27	1.25	5.20	10.90	1.24	0.47	5.10
Water of combination	3.60	4.93	6.03	1.07	2.17	1.27		11.01	2.40	0.36	
*Phosphoric Acid	32.36	31.69	32.00	39.62	29.99	34.03	23.45	33.70	26.85	42.34	27.48
Lime	47.28	38.00	43.06	50.04	42.20	43.25	40.48	28.00	42.96	51.63	43.00
Carbonic Acid	3.20	2.40	5.30	7.55	4.15	3.26	4.83	3.70	7.06		4.60
Oxide of Iron	1.93	4.25	3.05	traces	5.15	2.40	2.97	various undet'd 8.01	4.16		3.40
Alumina	1.03	8.81	2.20	0.45	0.12	4.51	2.15		3.01		1.09
Sulphuric Acid	traces	1.10	traces	traces	traces	traces	1.30		0.76	5.20	1.04
Fluorine	2.87		0.72	traces	1.71	traces	0.94		1.15		0.47
Insoluble Siliceous Matters	6.53	3.09	2.11	0.52	13.24	10.03	18.68	4.68	10.41		13.63
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
*Equal to Tribasic Phosphate of Lime	70.55	69.85	69.75	86.37	65.40	74.20	51.22	73.45	58.53	92.30	59.97

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If in the same way we add magnesia and ammonia, the phosphoric acid will at once fly to them, and, as ammonia-phosphate of magnesia, will fall to the bottom; and so on, until one after the other, we have secured all the ingredients which the solution contained.

The ammonia-phosphate of magnesia which has been deposited as a sediment, is separated from the liquid by passing the whole through filtering paper, from which, after it has become dry, the powder left behind is easily collected.

This powder is then submitted to the most intense heat, and is thereby transformed into calcined or pyro-phosphate of magnesia, the object of the burning process having been, to drive off the ammonia and any other foreign bodies, which have not, like magnesia-phosphate, the property of resisting extreme temperatures.

Pyro-phosphate of magnesia, being composed of known parts of phosphoric acid and of magnesia, we accurately weigh our calcined product; and, supposing, for the sake of illustration, its weight to be fifty grains, we immediately know that the substance analyzed contains thirty-two per cent. of phosphoric acid, and by a similar system of calculation, arrive at the equivalent of this quantity in phosphate of lime.

Before quitting the subject of mineral phosphates, it will be advisable to mention the discovery of large deposits in the Island of Alta Velta, near San Domingo, of a mineral which was at first mistaken for phosphate of lime, and as such, shipped in considerable quantities to European ports.

Upon complete analysis, it was found to be phosphate of alumina and iron, with very little lime, and a huge outcry was raised against it by leading London analysts, who denounced it as of no value to agriculture.

The cargoes which had already been shipped were consequently refused by the consignees and thrown upon the market at very low prices; but so great was the prejudice against them, that we have never heard of their having met with any purchasers. The detailed composition of these phosphates is shown in the following analysis, made from a fair and well-selected sample:

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Moisture	12.36
Water of combination	4.13
*Phosphoric Acid	30.22
Lime	4.16
Magnesia	Traces.
Oxide of Iron	7.04
Alumina	24.00
Carbonic Acid	None.
Sulphuric Acid	"
Fluorine	Traces.
Insoluble Sandy Matter	18.09
	100.00

*Equal to 65.87 per cent. of tribasic phosphate of lime.

It would be well if our chemical brethren would remember that as we have already described in these pages, phosphates are invariably found in our vegetable soils, as phosphates of peroxide of iron and alumina, and that, although some difficulty may attend their decomposition in the factory, or their transformation into chemical manures, they would be extremely valuable in the raw state — if very finely ground — as a direct manure.

The fact, however, of an abundance of phosphate of lime being always obtainable at very reasonable prices, has interfered with a general popularization of the facts, and it is only in the event of an increased demand, or a momentary decrease in ordinary sources of supply, that our prejudiced friends will suddenly discover in these phosphates a very valuable reserve to fall back upon.

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CHAPTER XII.

SULPHUR —— ITS OCCURRENCE IN NATURE —— THE MINES OF SICILY —— THE REFINING PROCESS —— ICELAND SOUFRIÈRES AND SOLFATARAS —— USE OF SULPHUR IN MANUFACTURE —— PYRITES AND HOW THEY OCCUR —— ANALYTICAL TABLES —— GENERAL ANNUAL CONSUMPTION —— THE MINES OF SPAIN DESCRIBED.

The practice of facilitating the solubility of phosphates by dissolving bones in oil of vitriol (sulphuric acid), originated with Baron Liebig, in about 1851, and it is only natural that the same idea should have been applied to the mineral or earthy product.

In order that our readers may thoroughly understand the process of decomposition, to which phosphatic materials are subjected in the manufacture of superphosphates and other chemical manures, it will be necessary and useful to explain what sulphuric acid is, and how it is made.

It has been said, and been said truly, that the prosperity of an industrial country is to be judged of by its production and consumption of sulphuric acid; and as it forms the basis of all chemical industry, and is largely employed in nearly every important branch of manufacture, the reason for the assertion can be easily understood.

As its name implies, it is derived either directly from the distillation of sulphur (brimstone), or from the burning of mineral sulphurets, known as *pyrites;* and before broaching the manufacturing question, let us acquire some knowlege of these raw materials.

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SULPHUR (or BRIMSTONE) is found in nature in abundant quantities, and may even be said to exist in nearly every rock, and to be closely associated with all mineral ores, copper, silver, zinc, lead, tin, iron, etc.

Its abundance in copper and iron ores is sometimes sufficiently great to turn them into sulphurets, and these are, to-day, the principal sources from whence sulphur is derived for acid manufacture.

The chief deposits of brimstone are found in Italy, France, Spain and Greece, but those of the first-named country are by far the most important, and have hitherto been capable of furnishing to the whole world the bulk of the required supply; the mines of Sicily alone being credited with a production of 250,000 tons a year.

In its raw natural state it is amorphous, and of a yellowish brown color, being associated with sulphate of lime (gypsum), sulphate of barytes and carbonate of lime.

The working of the mines in most cases is conducted by means of shafts or pits, sunk in the deposit, and are most primitive and totally devoid of modern machinery or appliances. They are provided with ladders on each side, and up these the mineral is carried in small wicker baskets, on the backs of children, their loads varying from thirty to seventy pounds, according to their age and strength.

Serious accidents frequently occur to the men engaged below, through the falling of these baskets before they reach the surface.

Near the mouth of each pit are built a series of kilns, like lime kilns, calculated to hold from 300 to 400 tons of sulphur at one charge. When the children arrive at the top of the shaft, they pitch the contents of their baskets into these kilns until they are quite full, when the fire is applied, and the brimstone, reduced by the heat to a liquid form, falls into a sort of basin at the bottom.

From the basin it is run off into moulds, whence it emerges in blocks of a reddish brick color.

In this preliminary process of separating the sulphur from its grosser impurities, a serious loss of weight is incurred, amounting

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in some cases to about one-third of the bulk, and arising from the escape of the sulphurous acid gas.

The rough product thus obtained is sometimes shipped without any further refining, and is worth twenty dollars per ton ; but in many cases it is further transformed into pure sulphur of a higher value, by sublimation and condensation in iron retorts.

In the volcanic district of Reykjalid, in the North of Iceland, a series of sulphur springs are met with, which afford a most interesting study.

They are of two kinds : those on the mountain slope consisting of hot gases, which arise from the earth, charged with sulphuric acid, hydrogen, sulphurous and aqueous vapors, and undergo decomposition by coming into contact with the atmosphere. The others at the foot of the mountain, being springs of black and boiling mud.

Mr. C. S. Forbes in his interesting volume on *Iceland, her Volcanoes and Glaciers*, gives a very graphic description of some of these springs, and in one of his chapters, he says :

" In the valley beyond, about fifty feet beneath us, lay a large cauldron, twelve feet in diameter, in full blast, burning and seething, with boiling blue mud that spluttered up in occasional jets, five or six feet in height, diffusing clouds of vapor in every direction. If a constant calm prevailed here, instead of ever-varying gales, the sulphur sublimated from these sources would be precipitated in regular banks ; as it is, it hardly ever falls twenty-four hours in the same direction, the wind blowing it hither and thither, capriciously distributing the sulphur shower in every quarter.

" Such, with little variation, save in locality, were the numerous Soufriéres and Solfataras that we visited, and they extend over a space of twenty-five miles. The riches of the district consist not so much in these numerous crusts of almost pure sulphur, as in the beds of what I must be permitted to term sulphur earth, which are promiscuously scattered in all directions, ranging from six inches to three feet in thickness, and containing from 50 to 60 per cent. of pure sulphur."

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Until about fifty years ago, the custom prevailed in Europe, which largely prevails in this country, of manufacturing the acid exclusively from sulphur; but in 1838, the king of Sicily was sufficiently ill-advised to grant a monopoly of the Sicilian sulphur trade to a commercial firm in Marseilles, France, and the consequence of this, as of all other monopolies, was to create for the article an unfair and fictitious value.

From twenty-five it was advanced to seventy dollars per ton, and thus all large manufacturers were induced to seek for their raw materials in other directions.

Some idea of the energy displayed in the endeavor to find this required substitute, may be formed from the fact mentioned in one of Baron Liebig's letters, in which he says that during the short existence of the Sicilian monopoly, no less than one hundred and fifty patents were taken out in Europe for the production of sulphuric acid from gypsum (sulphate of lime) the whole of which were, practically speaking, industrial failures.

That the substitute was eventually found, we are presently going to see, and brimstone is now principally used in making gunpowder, and for bleaching, and medical purposes; although if, in price and other advantages, it can ever vie with pyrites, there is no reason why it should not again be the basis of the manufacturing process.

PYRITES are sulphurets of antimony, arsenic, cobalt, nickel, copper and iron, the two last being chiefly used for sulphuric acid manufacture. They occur in immense deposits all over the world, and mines are now in active work on a large and continually increasing scale in the United States, England, Wales, Ireland, France, Belgium, Germany, Norway, Sweden, Spain, Portugal and Canada.

The annual quantity of pyrites consumed in the United States, Great Britain, France and Germany combined, is estimated at 1,750,000 tons, of which Great Britain alone takes over 850,000 tons, and the United States 175,000, the other two countries sharing the balance in almost equal proportions.

The following table of analyses will show the average composition of those ores, which have hitherto been found most suitable,

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there being many which, on account of their large percentage of arsenic are looked upon with general disfavor.

	Spanish.			Belgian.	English.	Irish.	German.	Swedish.	Canadian.	Virginian.
	1.	2.	3.							
Sulphur	47.50	49.90	49.07	42.80	34.34	47.41	45.60	38.05	40.00	48.02
Iron	41.92	43.55	44.28	36.70	32.20	41.78	38.52	42.80	35.00	42.01
Copper	4.21	3.10	2.75	None.	0.80	1 93	None.	1.50	5.25	None.
Arsenic	0.33	0.47	0.38	0.20	0.91	2.11	Trace	None.	None.	"
Zinc	0.22	0.35	None.	0.40	1.32	2.00	6.00	None.	3.00	"
Lead	1.52	0.93	"	0.92	0.40	None.	0.64	"	0.35	"
Silica (Sand, etc.).	3.40		2.34	8.86	29.00	3.93	8.70	12.16	11.90	7.60
Oxygen, Alumina, Lime and other Matters not determined.	0.90	2.70	1.18	10.12	1.03	0.84	0.54	5.49	4.50	2.37
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

As Spain may be considered, not only the principal source of present supply, but an inexhaustible field whence we may expect to draw any quantity required during the next few centuries, we shall devote ourselves to a short description of the Spanish mines, regarding them as typical in all important points, of pyrites ore deposits.

They are situated in the mountainous regions of Andalusia, at a distance of sixty or seventy miles from the port of Huelva, whence they are principally shipped for their different destinations. The surrounding rocks belong to the "lower silurian" series, and are of a schisty or slatey nature, intermixed here and there with greenstone and felspatic rocks of various descriptions.

The existence of these sulphurous copper ores has been known from time immemorial, they having been exploited first by the early Celts, then very extensively by the Phœnicians, and in due course by the Romans, who worked them for upwards of three hundred years, and left behind them traces of the gigantic nature of their operations, which are still to be seen.

When the Roman Empire had fallen, and while the Moors were in possession of the country, the mines were abandoned, and indeed,

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were left unworked, until about the middle of the last century, when an enterprising Swede endeavored to turn them to account.

The want, however, of sufficient skill and capital, combined with the difficulties of transport and the political troubles, which never ceased to convulse the country, caused all attempts to end in failure, until in 1873 the Spanish government decided to dispose of the properties by selling them to the company known as the Rio Tinto, limited.

The pyrites deposits are somewhat irregular and occur in lenticular shaped masses. There are three important lodes—the South, the Dionisio and the North ; the mineral resources of all three being so immense as to be considered by the best authorities inexhaustible.

The principal opening is that existing in the South lode, which is 1,500 yards long, 100 yards deep and 200 yards in breadth, and annually yields about 700,000 tons of ore, the composition of which is shown in our analytical table as Spanish No. 2.

Before this great lode could be worked, it was found necessary to remove nearly four million tons of earth, or overburden.

Beneath this immense bed of ore, which some engineers have estimated as containing about 200 million tons, are extensive underground workings reached by a tunnel already nearly 1,000 yards in length. When this tunnel attains a length of about three miles, it will connect and open out the *Dionisio* lode, upon which a shaft has already been sunk in the centre.

The great value of these sulphur ores is not confined to the manufacture of sulphuric acid, but, by the development of certain chemical bye-processes, has assumed considerable importance in the production of the precious metals ; thus, from the enormous amount of pyrites she annually consumes, Great Britain extracts in addition to the acid, about 18,000 tons of pure copper, 300,000 ounces of silver, 1,800 ounces of Gold and over 400,000 tons of iron ore.

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CHAPTER XIII.

SULPHURIC ACID MANUFACTURE —— SKETCH OF ITS PAST HISTORY —— PYRITES BURNING —— GLOVER'S TOWERS —— HINTS ON THE CONSTRUCTION OF LEADEN CHAMBERS —— CHEMISTRY OF THE PROCESS —— DENITRATION —— GAY-LUSSAC TOWERS —— GENERAL REMARKS.

Until Mr. Rodwell published his book, "The Birth of Chemistry," we had always been led to believe that the discovery of sulphuric acid was due to Basil Valentine, but we have now reason to suppose that it was known long before his time.

Pliny teaches us that sulphur was used for making matches and that sulphurous acid was employed for bleaching purposes, and produced by burning the mineral in contact with the air. Pyrites were also well known, and owe the origin of their name to their having been used for lighting fires by means of the sparks which they emit when struck by steel.

In the 8th century an Arab named Geber made sulphuric acid from the distillation of alum, and at the beginning of the 15th century, Basil Valentine commenced to manufacture it by submitting green vitriol (sulphate of iron) to distillation and made use of it in various processes and dissolutions.

After his time, several of the old chemists were engaged in investigating its properties and endeavoring to find out its true chemical composition, and among these, Paracelcus, the great Swiss alchemist who died in 1541, declared, as the result of his labors, that it was "nitre air mixed with sulphur."

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It was, however, reserved for one Gerard Dornæus to describe with tolerable exactitude what it really was, and this he did in a pamphlet published in the year 1570.

English makers originally prepared their acid by burning copperas in brick ovens at a high temperature, and condensing the vapors which distilled off, as an impure oil of vitriol, the commercial value of which was one thousand dollars per ton. This process gave way to the use of sulphur and nitre, burnt together in enormous glass globes and concentrated by boiling in glass retorts, the product being called "oil of vitriol made by the bell."

Passing on by successive stages, which we need not stop at, we arrive at the year 1746, and find the first leaden chamber erected in that year in Birmingham, by Messrs. Roebuck and Garbett, the proportions of raw material employed being seven or eight pounds of sulphur to one pound of saltpetre. This mixture was placed upon lead plates standing in water within the chamber, and was ignited by means of a red-hot iron bar, through a sliding panel in the wall.

Shortly after this time came the introduction of a separate apartment, for burning the sulphur in a current of air, which was regulated by a slide moving in the iron furnace-door ; the vapors being taken off through the roof into the adjoining chamber.

Progressively and finally we have arrived at our present position, and this will naturally continue to be improved upon as chemistry moves onward. The principal points in sulphuric acid production, requiring consideration by our contemporary industrials may be thus summed up :

A.—What kind of furnace or burner is best calculated to effect the complete combustion of the pyrites, including "smalls ?"

B.—What are the best dimensions to accord to the leaden chambers in which the combination takes place ?

C.—How to obtain the maximum results from the sulphur ore at a minimum expenditure of nitrate of soda ?

The manufacturer who has satisfactorily solved all these problems, may be said to walk in the very front rank, and has no competition to fear from any quarter.

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The best form of burner we have ever seen is that introduced by Mr. Spence, of England, the fire-brick hearth of which is about 40 feet long by 6 inches wide. It is fired from below, and receives the necessary air through an opening in the front, regulated by a damper. This oven will successfully burn pyrites in fine powder, perfect combustion being ensured by introducing them at the opposite end to the fire and gradually pushing them to the hottest parts. When once they have become fully ignited, no further fuel of any kind is required, as they will continue to burn until all the sulphur is exhausted.

At the mouth of the flue or chimney of these ovens, are placed cast-iron "nitre pots" containing a mixture of nitrate of soda and sulphuric acid, and evolving dense nitric acid vapors. Under the combined influence of the intense heat and the current of air passing through the furnace, the pyrites undergo total decomposition; the sulphur being driven off in the form of vaporous sulphurous acid, and the iron being transformed into oxide. When the sulphurous vapors arrive at the flue, they meet with those emanating from the nitre pots, and the two, immediately combining, pass off through large conductors built of lead and lined with brick, known as "Glover's towers," into large leaden chambers, where they are brought into contact with a considerable body of steam.

These chambers are constructed entirely of lead, weighing from six to seven pounds per square foot, and are generally put up in sets of three, connected by syphon and cistern arrangements for drawing off and storing the acid, as it is made. They are built upon a framework of timber, supported by iron columns, and all round their sides are placed small glass windows, through which the various colors assumed by the vapors, as the manufacturing process developes itself, may be plainly seen. At regular intervals between these windows, are found leaden syphons, which dip into small leaden tanks within the chamber, and permit of samples of the acid being drawn as required.

Endless discussion has taken, and continues to take place concerning the best size to be adopted for a chamber.

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Our own opinion is that those which are 125 to 150 feet long, 20 to 25 feet wide, and from 12 to 15 feet high, best answer the requirements — it being necessary to have them large for very important reasons; first, because of the bulk of the gases which enter, and the necessity for their coming into direct contact; and, second, because the air only contains in every hundred, 21 volumes of available oxygen.

Upon meeting with the steam, the sulphurous vapors combine with certain portions of its hydrogen and oxygen, and immediately become a liquid and tangible body — known as sulphuric acid, while the nitric acid vapors, casting off all their hydrogen, unite with the oxygen of the air and become nitric peroxide.

The sulphuric acid falls to the floor of the chamber, and the nitric peroxide passes out at the end opposite to that by which it entered, and is conducted into absorbing columns known as "Gay Lussac" towers, where it is absorbed in concentrated sulphuric acid, and, conducted by a complicated process back to the regions of the nitre pots, where it assumes its original form, and thus is continually utilized over again.

It is on the good and careful, or faulty working of this process of *denitration* that depends the saving or the loss in the consumption of nitrate of soda to which we have already alluded in a former chapter, and it has ever been the greatest difficulty with which chemists have had to deal. Without dwelling upon the various old-fashioned methods still in use in many factories, we will endeavor to give a rough outline of that which is now generally looked upon as most successful.

The "Gay-Lussac" columns, to which we have alluded, are named after the distinguished French chemist who invented them some forty years ago, and are high and narrow leaden towers packed with small lumps of coke and supported on a framework of timber.

The nitric peroxide and the other vapors which issue from the chambers are led into these towers through openings at the bottom, and are met in their ascent by a current of concentrated sulphuric acid, flowing in a small stream from a cistern placed over each tower and pumped up thither by a small forcing engine.

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This acid runs through the coke, and without chemical action, absorbs the peroxide of nitrogen and carries it downwards, allowing any other gases to pass on to the flue whence they escape into the air.

The concentrated nitro-sulphuric acid is weakened during its onward course by the introduction of newly made acid from the chambers, and in this state passes into the "Glover's towers" and meets upon its entry the vapors proceeding from the kiln at a temperature of about 700° Fahrenheit.

The immediate effect resulting from this encounter is the following:

The sudden contact with such intense heat, at once concentrates the acid to a density of 150° Twaddle, with a great evolution of steam.

The peroxide of nitrogen is seized upon with avidity by the sulphurous acid vapors and carried with the steam into the leaden chambers.

The concentrated acid falls into a reservoir below, whence it is returned by the forcing pump to the Gay-Lussac towers to serve over again.

It will be seen that if this process be thoroughly carried out, not only must there be a vast economy of nitre, but all the necessary strong acid for the Gay-Lussac towers is produced without the slightest expenditure of fuel for its concentration.

The cost of building leaden chambers being very considerable, it is only natural that many attempts should have been made to construct them from cheaper materials; we have therefore witnessed many trials of earthenware, stone, slate, glass and gutta percha, all of which have failed, owing to the rapid manner in which the acid has destroyed them.

It is estimated that there are now consumed in this country about 450 tons of pyrites every day, and that the total yearly production of sulphuric acid is about 600,000 tons, of which about 350,000 are made from sulphur.

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CHAPTER XIV.

SUPERPHOSPHATES —— UNCERTAINTY OF THEIR COMPOSITION —— THEIR MANUFACTURE DESCRIBED —— HOW TO MANIPULATE WHEN MADE —— NATURE OF THE DECOMPOSITION PROCESS —— EXPLANATION OF THE LOSS IN WEIGHT —— WHAT IS SOLUBLE PHOSPHATE ? —— DISCUSSION OF ITS MERITS IN THE FIELD —— ITS ACTION IN THE SOIL —— NECESSITY FOR CAREFUL ANALYSIS MADE FURTHER MANIFEST —— PRECIPITATED PHOSPHATES —— THEIR MANUFACTURE —— THEIR VIRTUES AND SUPERIORITY —— USE OF COMPLETE MANURES WITH EXAMPLES AND STATISTICS —— REMARKS ON HOME-MADE CHEMICAL MANURES.

The process of superphosphate manufacture, whether it be from bones or mineral phosphates, is neither a very complicated nor difficult one, but it requires a certain amount of chemical knowledge and experience which the majority of those concerned in it do not possess ; and hence it is, that no article in the market is more variable, both in its physical condition and chemical composition.

Nor can this remain a source of surprise, when we remember that each manufacturer adopts some peculiar system of his own, and that no two chemical factories bear any resemblance to each other.

Like every growing industry, it has been invaded by capitalists, who have seen in it a possibility of realizing large interest on their investment, and who, devoid of even elementary true knowledge, have begun producing manures without the aid derived from practice and observation.

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There are consequently huge quantities of superphosphates, constantly foisted upon the farmer, which, made in ignorance, purchased in ignorance, and used in ignorance, sometimes produce satisfactory results, but more frequently give no proportionate or immediate return for the money they have cost.

If a thousand tons of phosphate of lime be given to one manufacturer, he will transform it into a fine and dry acid phosphate, in which every particle of phosphoric acid has been made available; and if the very same quantity of the same material be entrusted to his next-door neighbor — who to the uninitiated possesses the same facilities — he may very possibly turn out a moist, pasty substance, in which more than half the phosphate will be found insoluble.

As the readers for whom these pages are written are not supposed to be producers, but consumers of manures, we shall not attempt to discuss the reasons for the unfortunate lack of homogeneity; but shall merely sketch out the process by which superphosphates should be made, if they are to fulfill the conditions required by the advocates of their application.

Assuming ourselves to be dealing with the manufacture on a large scale, and in connection with the production of sulphuric acid, the first step to be taken is the reduction of the raw material to a powder, rivaling in degree the finest wheaten flour.

Various more or less efficient systems of pulverization have been introduced and adopted, but it will serve no useful purpose to describe them, the form of implement being of small importance providing the object is attained.

The finely ground material is generally turned directly into sacks, weighed by mechanical agency, and laid aside ready for use.

The mixture with the acid is performed in a commodious shed, made to communicate with a high chimney or shaft, so as to carry off the noxious vapors of fluoric, silicic and carbonic acids and chlorine which are always more or less evolved by all phosphates during the reaction. In the centre of the floor of this shed, should be built, with a good foundation, a strong brick-work shell, divided into four or six chambers or dens.

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Each den should be about 12 feet square and 15 to 20 feet high, and must communicate with the shaft or chimney, by means of a good-sized opening, situated near the top, while the air-tight iron doors by which they are entered must slide easily, when pushed backwards or forwards.

Upon the top of each den is fitted a mixer of cylindrical shape, 3 feet in diameter and 4 feet high, made of lead, and encased in a strong wooden frame, with a movable bottom or trap. It must be provided with a large hopper or feeder, and possess a revolving axle fitted with arms or spirals.

Running into each mixer from the top, under the hopper, is a leaden pipe fitted with a glass stop-cock communicating with a tank placed directly overhead, and prearranged by mechanical appliances to let out only a calculated quantity of liquid for each batch. This tank communicates in its turn, with the acid chambers from which, when emptied, it is automatically replenished.

The phosphate is either brought forward from the mill in buckets, by what are known as Jacob's ladders, or wheeled up an inclined plane and emptied into the hoppers of the mixer, where, the acid tap being turned on, the powder and the liquid work into the drum together.

The agitators are allowed to revolve with swiftness and energy for about five minutes, when, the sliding bottom of the mixer being withdrawn, the whole contents in the form of a thick mud are allowed to drop from the drum into the den.

As the acid in the leaden chambers is frequently found to be deposited in layers of different strength, care must always be taken to test and thoroughly mix it before allowing it to enter the tank from which the phosphate mixers are supplied,—a want of uniformity in this direction being generally, if not always, attended with loss and disappointment. At the end of 24 hours the doors of the dens may be opened, and, if the proportions of the raw material have been properly calculated, the superphosphate will then be sufficiently hard to allow of its removal with the shovel.

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The transformation undergone by the mineral will be understood, by calling to mind that phosphates of lime are tribasic, that is to say, composed of three parts of lime to one part of phosphoric acid, and that in this state they are totally insoluble in pure water.

When the sulphuric, which is the strongest acid, is brought into contact with the powder, it drives away all the carbonic, fluoric and silicic acids, and, depriving the phosphoric acid of two of its equivalents of lime, forms them into sulphate (gypsum). The phosphoric acid, thus left with only one equivalent, becomes mono, or meta-phosphate, which is soluble in water. It follows from this that unless a sufficiently large proportion of sulphuric acid be used to completely effect this transformation, a certain quantity of the phosphates will retain their primitive tribasic state, and be shown as insoluble when the manufactured article is submitted to analysis.

As a final result of the above chemical decomposition, the difference in the weight of the raw materials and the manufactured product will be considerable, but should, nevertheless, not exceed 6½ or 7 per cent. This loss, however, chiefly arises from the disappearance of the gaseous elements driven away by the sulphuric acid, and in no way affects the quantity of phosphoric acid. Thus, for example, presuming the proportions used, to have been 200 pounds each of sulphuric acid and tribasic phosphate of lime, we should find the weight of the superphosphate to be 372 pounds, and that of the mono-phosphate to be equivalent to 120 pounds of tribasic phosphate of lime, or rather more than 30 per cent.

Farmers believe the word "soluble" to mean that the acid phosphates, when put into the ground, at once dissolve, and hence that their use is much more advantageous than that of phosphates in their raw state.

The time has come for a correction of this misapprehension and for a recognition of the true phenomenon; because, if farmers are to be scientific, they must at least understand something of the elementary chemistry of their operations.

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We have already seen how most of the ingredients placed in the soil are absorbed and made available for plant food. It will therefore be unnecessary to add that none of the manures are assimilated *in the form in which they are introduced.*

Thus acid phosphate, sold as *soluble,* and found upon analysis to answer the required test, simply means that, so long as the sulphuric acid maintains possession of the lime it has taken from the phosphoric acid, the latter has only one base, which its own acidity enables it to dissolve when immersed in the water; but place these matters in the ground — where the carbonates are in excess — and the sulphuric acid is at once overpowered and the phosphoric acid set free.

The latter element, being unable to exist in nature in a free state, or in any other than a tribasic form, unites once more with the lime and iron of the soil, and so at once practically reassumes the same chemical form it originally wore when tipped into the mixers at the factory.

The question naturally arises, under these circumstances, whether it is of any use continuing the employment of acid, soluble, or superphosphate, and whether it would not be wiser to at once adopt the direct application of the raw material? Some chemists having declared that young rootlets are frequently destroyed by the corrosive action of the sulphuric acid. (?)

The original idea of mixing the acid with the phosphates in order to render them more easily assimilable, arose from the impossibility of reducing either bones or mineral phosphates to such a high state of division and disintegration, as to make them easy to grapple with and decompose by the chemical elements in the soil.

The whole theory of Liebig, therefore, was, that what could not be done mechanically, chemical means could easily effect. And the best proof of the complete disintegration or dissociation of the elements in the mixing process, is to be found in the formation of sulphate of lime, and the consequent deprivation of the phosphoric acid of two of its bases; so that, while it is undeniable that tribasic phosphate is immediately reformed in the soil, we consider it to be reformed in such a conveniently disseminated manner, as to facilitate

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its attack by the carbonic acid and render its subsequent solubility a work of comparative ease.

In lands which contain an abundant or even a moderate supply of lime, there can, consequently, be no doubt as to the rapid decomposition of the acid phosphates, and the assimilation of their phosphoric acid. But where both difficulty and danger may be encountered is when an absence or deficiency of lime characterizes the soil. For in such cases, not only will the phosphoric acid remain unassimilable, but the excess of free sulphuric acid may exercise a corrosive action on the roots, or combine with the oxides of iron to form sulphate, the baneful properties of which we have dwelt upon elsewhere.

The arguments in favor of soil analysis, constituted by these considerations, appear to us to be conclusive, and they will not fail to add their weight to our oft-repeated assertion, that to know what elements to apply and in what form to apply them, we must first of all possess perfect information on the physical and chemical properties of the lands under treatment. Do they lack phosphoric acid, and have they plenty of lime? Then superphosphates are the natural prescription. But if they are shown to lack a sufficiency of both phosphoric acid and lime, they must either be well limed first, and afterwards receive the superphosphates, or we must devise some other form, in which the two necessary matters may be simultaneously plowed in, with the prospect of obtaining speedy and beneficial results.

We have already striven to impress our readers with the belief that the origin of manures, or the form in which they present the needful constituents, are both utterly insignificant, providing those constituents be of a nature to become at once available for the crops. We shall therefore be understood when we say that our own tendencies, based upon long experience and experiments, are in favor, wherever it is possible, of substituting the use of *precipitated* phosphates for the acid supers.

Precipitated phosphates are obtained by dissolving the raw and finely powdered phosphatic material in muriatic acid, which, when

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it has taken up as much as it can possibly retain, is neutralized by the addition of carbonate of lime (common chalk).

The deposit which ensues from this operation is allowed to accumulate, and the clear liquid is then decanted off. When thoroughly dried, the precipitate will be found to contain from 75 to 85 per cent. of tribasic phosphate, in a state of physical division, which, for similar chemical reasons, is common with that of superphosphate. It is therefore easily decomposed by the alkaline carbonates in the soils, and made soluble by the carbonic acid.

We have heard it maintained, that the price of this preparation is too high to permit of its being generally used in sufficient quantity, and that superphosphates, having stood the test of time, had given results which, upon the whole, were satisfactory.

On general principle we shall not attempt to deny these assertions, any more than we shall refuse to admit that established interest and prejudice are both in their favor; but we, nevertheless, submit that, where the choice is between two articles—one of which is shown not only to have weak points but to sometimes be harmful, whereas the other is infallible, the acquisition of the latter is a true economy.

We shall therefore be very glad, even if it should necessitate a small monetary sacrifice, to see precipitated phosphates more largely and frequently employed; although we give out the idea with a full consciousness of the vast difficulties which attend the marking-out of rigid lines for the cultivator's guidance.

The farmer holds in his hands the threads of his own prosperity and the elements necessary to his own success; he possesses the compass, by means of which his bark can be steered into port with flying colors; and this compass is his intimate acquaintance with the soil he tills. Just as the best of armies are paralyzed without a leader, so the best and most accomplished chemists can never give a sound opinion, when they have not the results of complete investigation to guide them.

In the course of our remarks upon farm-yard manures, we have laid great stress upon their utter inadequacy to restore the necessary

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elements in sufficient quantity to the soil, and even when, by working into the compost heaps a sufficiency of phosphatic materials, we bring up the phosphoric acid to the requisite standard, they will still lack other elements to make them perfect.

A complete manure may be defined as that which puts back, in its true proportion, each element taken away by the preceding crop. And to exemplify this, we take a crop of wheat, estimating the average production at 38 to 40 bushels of grain per acre, or at 4,750 pounds in weight including the straw. On the basis of our previous calculations, we shall find that this crop has approximately taken from the soil :

55 pounds of Nitrogen,
25 " " Phosphoric acid,
30 " " Potash,

without counting the lime, the silica and other matters, which we shall presume a good old soil to contain in sufficient quantity ; and that, therefore, if we wish the production to be maintained, the same amounts must be returned.

Now, the calculation of the requisite quantity of well-made farm-yard manure to represent the nitrogen, can be easily made, since we have already shown that in every hundred pounds there is about half-a-pound of this precious fertilizer :

½ pound Nitrogen = 100 lbs. farm manure.
55 pounds " = 11,000 lbs. " " or 5½ tons per acre.

And our experience has taught us that of all those who farm, say, 50 acres of land, there are very few who can produce 275 tons of high-class stable dung !

We must consequently look to compound fertilizers of chemical manufacture to supply the deficiency, unless within easy reach are to be found such articles as we have tabulated on page 49, in a form adapted to convenient manipulation.

So many difficulties are connected, however, with the manufacture of chemical fertilizers on the farm — in arriving at the proper proportions, in the constant attendance to the perfect working and decomposition — that we have come to consider the abandonment of

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home-made chemical manures as the natural outcome of practical experiment.

The manufacturer who has suitable works, and produces on the large scale; who has the needful knowledge and practice, and the needful implements at hand, buys his raw material by cargoes to the best advantage. He can therefore very easily furnish well-made compound manures, and guarantee them by chemical analysis to contain the elements desired, at a price which, all things considered, will be less than the cost of home fabrication.

With soluble or precipitated phosphates as the basis of operations, we can now obtain complete manures for every culture, made according to any formula, and containing in a readily available and assimilable form all the ingredients called for.

The raw materials having already been dwelt upon, and their attributes and chemical composition described, it is only needful to add that when the due proportions of each kind have been accurately weighed, they are all mixed up together by special machinery, and so carefully ground, sifted and blended, as to make it impossible to distinguish with the naked eye that any mixture has taken place.

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CHAPTER XV.

CHEMICAL ANALYSIS —— HOW TO READ AND UNDERSTAND CHEMISTS' CERTIFICATES —— USE OF "COMPLETE" AND "SIMPLE" MANURES —— CONCLUSION.

If we were now asked to pithily sum up the great practical conclusion to be drawn from our lessons, we should reply, not "Farmer, know Thyself!" but, Farmer, know thy soils and analyze thy manure;" believing as we do, in all sincerity, that this is the sum of intelligent high farming.

The mere possession of an analysis, however, conveys no information, unless it be thoroughly understood, any more than a hundred pounds of candles would be of any service to a man in a dark room, if he had nothing to strike a light with; and we shall therefore endeavor to translate the meaning of the statements made by chemists in their certificates.

THE MOISTURE is the water which is introduced into the mixture by the weak sulphuric acid, and in a properly prepared compound should never exceed 12 to 15 per cent. The sellers of chemical manures should invariably be required to guarantee a minimum of each active element contained in a given product, *in its normal state.*

Thus, for instance, a sample of superphosphate taken at the works, may, when despatched by mail, have contained 20 per cent. of moisture and 10 per cent. of soluble phosphoric acid; but between the time of its dispatch, its arrival at destination, and its analysis by the intending purchaser, so small a sample may have suffered the loss of 5 per cent. in weight by evaporation.

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Presuming, therefore, that it originally weighed 10 ounces, it will then only weigh 9½ ounces, and nothing but water having been lost, these 9½ ounces will now contain 12 per cent. of phosphoric acid.

If the manure be purchased upon this sample without further analysis, as frequently occurs, the buyer will pay on the basis of 12 per cent. but will, in reality, only receive 10 per cent. and so incur a loss of $1.50 or $2.00 per ton.

In many instances, farmers are induced to buy manures at so much per ton, guaranteed to contain, *in the dry state*, certain proportion of the active elements. When analyzed, they are found to be loaded with 20 or even 25 per cent. of water; and therefore, if sold as containing, say, 20 per cent. of acid phosphate, will only contain 15.

Organic Matter consists of all substances subject to decomposition by fire, or to natural decay: — hair, wool, woody fibre, cotton, vegetable and animal refuse, are consequently placed in this category by the chemical analyst. The value of their presence lies in their percentage of nitrogen, and this being very variable indeed, the addition of the words nitrogenous, or non-nitrogenous, and the indication of the equivalent quantity of ammonia, should always be demanded. Where this precautionary measure is neglected, very grave misapprehensions frequently ensue, from the simple fact that common wood-shavings, mixed into a manure, would be truly stated as organic matter.

When these words are qualified by that of "nitrogenous," a glance at the foot of the certificate should show us the equivalent in ammoniacal salts. Thus in Peruvian guano, it was no uncommon thing to find 50 per cent. of nitrogenous organic matter, containing 17½ per cent. of ammonia, and equal to 14½ per cent. of nitrogen; and hence the prevalent custom for unprincipled traders to manufacture spurious guanos, which were bought by the unsuspecting farmer, under the impression that the term "organic matter" was just as significant of value in the one case as in the other.

Soluble Phosphoric Acid represents, as we have already pointed out, the quantity of phosphate of lime made soluble in water by the excess of sulphuric acid. For example: a superphosphate of 12 per

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cent. guaranteed strength is equal to 26.16 per cent. of tribasic phosphate of lime, but not of biphosphate, or monophosphate, as might be easily supposed, and of which no more than about 17 per cent. would be present.

When buying phosphatic manures, it is always well to have a distinct understanding as to the word soluble, as many makers produce an article which, though only partially soluble in water, readily dissolves in citrate of ammonia. It frequently happens that a superphosphate, even when made with all care and skill, suffers from the subsequent reaction of the iron and alumina, what is called a retrogradation or going back to insolubility, and when this is so, becomes only partially soluble in water, while remaining entirely soluble in the other liquid named.

INSOLUBLE PHOSPHATES only occur in cases where imperfect decomposition and want of skill have characterized the manipulation; and as no *immediate* benefit can be derived from applying them to the soil in this form, which cannot be as readily attained by using raw phosphates, the value should be brought down to the actual market level of the latter. Presuming, for instance, the soluble phosphates to be worth one dollar per unit, these insoluble matters must not be charged at a higher rate than twenty to twenty-five cents.

SULPHATE OF LIME results from the process which goes on in the mixers already described. It invariably exists in large proportions in all superphosphates, and its chemically great affinity for water facilitates the drying of compounds which, in many cases, would otherwise retain the form of paste. Its efficacy is well recognized, and, as plaster of Paris, or baked gypsum, it is frequently purchased and applied with good results to grass lands.

This gypsum is not taken into consideration, in fixing the value of a manufactured manure, and the farmer who has been in the habit of buying plaster of Paris, may cease this outlay from the day he commences to use superphosphates, it being no longer necessary.

ALKALINE SALTS generally consist of sulphate of soda and potash, in ordinary mineral superphosphates, and in their case are too insignificant to require any special attention.

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When compound manures are in question, however, this heading will comprehend the potash and any nitrates that may have been added to them, and will then be of considerable importance. It is the common practice when estimating the nitrates, to add the quantity of nitrogen they contain to that found in the organic matter, and calculate the equivalent of the whole as ammonia.

Even in cases where no organic matter exists, the same mode of estimation can be applied, as, supposing the manure to contain 7½ per cent. of nitrate of soda, it will be equivalent to 1½ per cent. of ammonia, or 1¼ per cent of nitrogen. The potash salts are chiefly found in manures, either as muriate or nitrate, and their value is determined by reducing them to their equivalent in pure potash.

Insoluble Siliceous Matter means the earthy and sandy bodies forming the gangue by which all mineral phosphates are surrounded, and from which it is impossible to entirely free them. In superphosphates or compound manures, the very maximum quantity of these useless substances should be 6½ to 7 per cent., and anything above these figures would suggest to our minds the addition of some worthless rubbish, with a fraudulent intention.

As complementary to this explanation of the various constituents, shown by chemical analysis to make up the composition of a manure, it will be wise to give a practical illustration, and we therefore append the analysis of a "phospho-guano," or artificially prepared guano, dissolved in sulphuric acid.

Moisture	9.12
*Nitrogenous Organic Matter	38.57
Phosphoric Acid Soluble in Water	13.20
Insoluble Phosphate of Lime	5.01
Sulphate of Lime	19.26
†Alkaline Salts	9.97
Insoluble Matters	4.87
	100.00
*Containing Nitrogen	9.00
Equal to Fixed Ammonia	10.92
†Containing Potash	2.75

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Where Stassfürt salts are used by manure manufacturers, a considerable danger sometimes arises from their containing a serious enemy to vegetation, in the form of chloride of magnesium, which, when not driven off by the application of sufficient heat, constitutes a positive poison to plant life.

When the lands under cultivation are characterized by the homogeneity, or equally balanced proportion of their chemical elements, the yearly application of compound, or "complete" manures will sustain their health and strength, and increase their fecundity, but where, as in most cases, one of the essential elements is alone found to be wanting, the others being present in abundance, the temporary employment of a "simple" manure is clearly indicated.

Supposing, for instance, a soil to be rich in nitrogen and potash, but devoid of phosphoric acid, and presuming cereals to be the desired culture, the repeated introduction of phosphatic materials will accomplish what is necessary, until after about the third crop, when the nitrogen will probably have become exhausted.

That the eventual recourse to compound or "complete" manures is essential, therefore, may be considered conclusive, even if we had not for our guidance the experience of our grandfathers, who, having always contented themselves with their stable offal, were finally compelled to take refuge in the system of rotation, because their manures were incapable of returning, *pro rata*, the elements their crops had taken away. To set forth any general formula for universal use and for every kind of culture, would be as contrary to our theories as the swallowing of quack specifics for every human ill is against our practice, nor would it be consistent with the doctrine, "do all that you have to do with a full knowledge of what you are doing!"

It is time that what has been so long and so exclusively known to chemists, should become known to the farmer, and that of two things he should at once choose one. Let him either deny the truth and boldly refuse to be convinced, or fall into the ranks and profit by those lessons taught by nature. They who, dissatisfied with the miserable results of their traditionary usages, seek to raise their minds

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to the level of modern science, will hardly fail to perceive how coarse and ignorant is that prejudice, how base and grovelling those capacities, which still refuse to recognize its wondrous revelations.

The fossilized systems which were good enough for a by-gone age cannot any longer assimilate with our gigantic progress. They do not keep step with the conceptions of natural law and order forced upon our minds by modern thought. Are not agriculturists, of all men, the ones to deal with that question which dominates all others in natural interest and importance — the question of our food supply? When placed upon the scale of sober judgment with every other social problem, does not this one outweigh them all, and come crashing down like lead when weighed with feathers?

Is it not to feed our children that we make all the best efforts of our lives? And where the food of nations depends upon the issue, should not every reasoning being lend strength to tear aside that curtain which hides the sun of knowledge and holds men's minds in ignorance and darkness?

We are stepping on far, we are stepping on swiftly. The Schools are rendering us assistance, and hurrying us on to emancipation; and so surely as the intellect develops and expands, so surely will the modern farmer cast aside the last remnants of his prejudices, and, seeing that the turn has come in the tide of his affairs, will take it at the flood and be led on to fortune.

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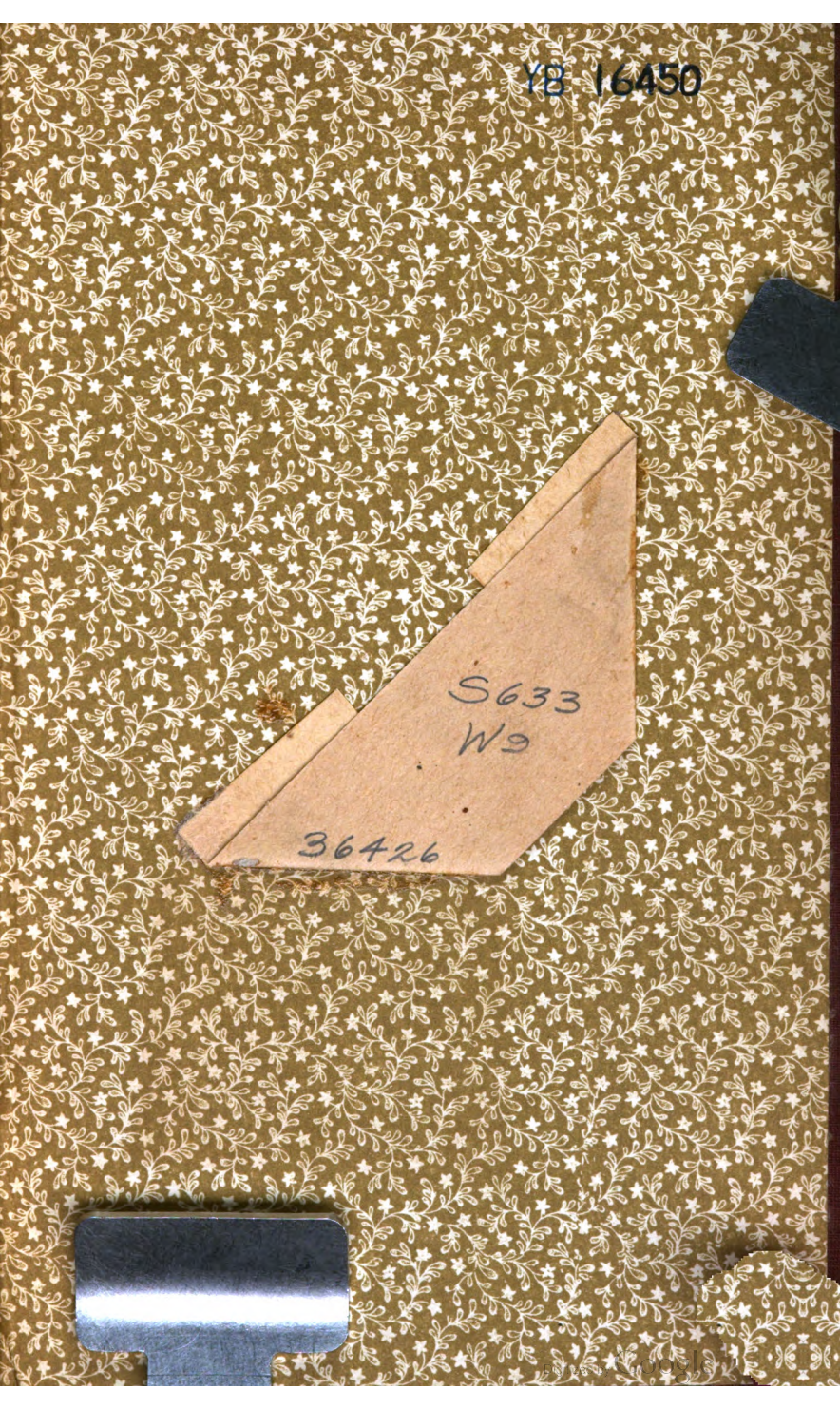
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